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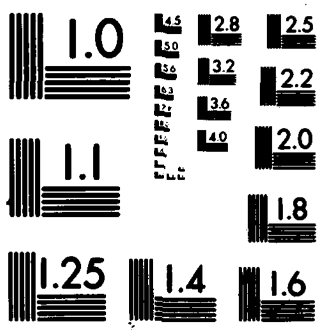
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ENVIRONMENTAL AND CULTURAL IMPACT

PROPOSED TENNESSEE COLONY RESERVOIR

JAN, 1972

TRINITY RIVER, TEXAS

by

STEPHEN F. AUSTIN STATE UNIVERSITY

Nacogdoches, Texas

BOTANY | EUTROPHICATION | LAND USE
ZOOLOGY | PESTICIDES | HISTORY
GEOLOGY | HYDROLOGY | ARCHAEOLOGY

VOLUME III

APPENDICES D AND E

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This is an interim report of the study concerned with environmental and cultural impacts of the proposed channelization of the Trinity River. This publication presents data concerning the environmental impact of the proposed Tennessee Colony Reservoir. This interim report consists of five volumes: volume one contains the summary report; volume two contains archaeological and historical elements, geological elements, and botanical elements; volume three contains zoological elements and eutrophication and pesticide elements; volume four contains forest hydrological and soil conditions for watershed – –

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20. management; and, volume five contains conceptual land use elements.

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APPENDIX D

ZOOLOGICAL ELEMENTS

by

Charles D. Fisher

Fred. L. Rainwater

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BENTHIC MACROINVERTEBRATES OF THE TENNESSEE COLONY SITE

A. Factors affecting a benthic community

Macroinvertebrates associated with the bottom of a stream or river have served as a useful tool in detection of harsh environmental conditions, such as polluted water, especially organically enriched streams. They are relatively immobile, have aquatic stages lasting long enough to develop complex faunal associations, and serve as natural monitors of environmental conditions. Because of the importance of this group as monitors of adverse conditions, attempts have been made to set up criteria of abundance or to fix upon the presence or absence of certain "indicator" organisms as evidences of polluted environments. These "indicator" organisms have led to some confusion because of the limited range of certain species, because different environmental influences may have varied effects on the same species, and because some organisms abundant in polluted waters may also be found in reduced numbers in unpolluted water.

Natural biotic communities typically are characterized by the presence of a few species with many individuals and many species with a few individuals (Odum et al., 1960). Few species and often greater numbers of individuals characterize an unstable environment with limited habitat which may be caused by a number of factors such as, toxic substances, high turbidity, poor water quality associated with organic enrichment, and unsuitable substrate (i. e., sand, silt, or scoured stream bottom).

B. Areas sampled

Benthic macroinvertebrates were collected from seven locations in four tributaries of the Trinity River area to be inundated by the Tennessee Colony Reservoir. A hand operated Ekman dredge was used to collect these samples. Sixteen artificial substrate samplers were placed in four locations in the Trinity River at the Tennessee Colony Reservoir site. These samplers were used because the dredge proved ineffective in the river to collect benthic organisms because of its hard clay bottom. Data concerning the river samples are not available at the present time due to the continual high water level of the Trinity River which has made retrieveal of these samplers impossible.

The collecting stations of the Trinity River tributaries (Fig. 1-D) were;

Station 1 (Cottonwood Creek) at F. M. 833 bridge;
7 mi. NE of Fairfield.

Station 2 (Tehuacana Creek) at F. M. 488 bridge; 4 mi. SW of U. S. 287 - S. H. 488 junction.

Station 3 (Tehuacana Creek) at county road bridge; 5 mi. SE of Streetman.

Station 4 (Richland Creek) at F. M. 488 bridge; 12 mi. SW of U. S. 287 - S. H. 488 junction

Station 5 (Richland Creek) at county road bridge; 4 mi. N. of Streetman.

Station 6 (Chambers Creek) at F. M. 2859 bridge; 5 mi. SW of Kerens.

Station 7 (Chambers Creek) at S. H. 31 bridge; 5 mi. W. of Corsicana.

C. Major groups of benthic organisms

Relative abundance of benthic organisms from the tributaries indicated oligochaetes and dipterans to be predominant with generally a low diversity of groups of organisms and low population densities of all organisms in some areas (Table 1-D, Fig. 2-D). These data, however, are representative only of the collecting sites and changes in their abundance and community structure would be expected to occur with season and different substrate types within the streams. Table 1-D reflects the more common benthic groups of each area since limited sampling (once in October and once in November from each station) probably does not include minor groups which may be present.

Station 1 (Cottonwood Creek). The benthic community at this site was extremely low. Two groups, a culicid, Chaoborus and Lumbriculidae constituted 98 per cent of all organisms, while other chironomids made up only two percent of numbers of individuals. Both of the dominant groups are commonly associated with stagnant pools and ponds and Cahoborus is usually the dominant organism in the profundal zone of lakes where the bottom approaches anoxic conditions. The substrate was soft mud and appeared to be an optimum type for many burrowing forms which were not collected. Possibly the water quality element limited the benthic community but a chemical analysis of the water did not indicate any unusual properties which might be responsible for a low diversity. The reason for this benthic community to reflect a typically harsh or "polluted" environment is unknown, but the drainage basin for this tributary should be investigated for possible factors causing this situation.

Station 2 and 3 (Tehuacana Creek). The two sampling stations in Tehuacana Creek also showed an abundance of oligochaetes and dipteran larva, but several other groups invertebrates were also represented. The prevalance of lumbriculids and chironomids at station 2 is probably characteristic of the small streams of this area because of their fluctuating water levels during the year and the hard clay bottom. The upper Tehuacana Creek station (Sta. 3) contained a large population of mayflies (Hexagenia). This numph is generally associated with a soft mud bottom for their burrowing activites. This area of the stream had a more suitable substrate, soft clay, for this and other burrowing forms, hence a greater diversity of organisms.

Stations 4 and 5 (Richland Creek). The lower reaches of Richland Creek, including station 4, is influenced greater by runoff water than the other stations. Station 4 has a very hard clay bottom, similar to the Trinity River due to scouring from the increase flow, and therefore is less suitable for burrowing invertebrates. This station was poorly represented in both number of individuals (approximately 90 individuals/m^2) and kinds of organisms. While station 5 was not numerically abundant, it contained a more diverse fauna. The substrate here was a softer type which probably accounts for this difference.

Stations 6 and 7 (Chambers Creek). The numerical abundance of both stations on Chambers Creek was scant, but did contain several different taxa of benthic fauna. The substrate of the stream was relatively hard clay. Although mayflies were present here they were generally Stenonema rather than Hexagenia, and is not considered a burrowing form.

In general, the diversity and abundance of the benthic macroinvertebrates from the tributaries sampled appear to be governed largely by the substrate type, which in most cases is hard clay. The types of bottom dwellers of these tributaries are more typical of pools, ponds, and lakes than "typical" stream benthic fauna. The lack of riffles in these streams, widely fluctuating water levels, and scoured hard clay bottom probably account for the lowered diversity of benthic organisms which usually inhabit streams.

D. Changes caused by impoundment

While changes in the benthic population structure will be altered by impoundment, it would not eliminate the types of invertebrates presently in the tributaries. Most impoundments of this area, including ponds, develop a soft mud bottom as sedimentation progresses. The dominant lentic benthic forms are usually oligochaetes (Lumbriculidae and Tubificidae), dipterans (Chironomidae and Culicidae; mainly Chaoborus in the profundal zone), mayflies (Ephemeridae). Thus, the fauna presently in the tributaries characterize the same forms as would the proposed Tennessee Colony Reservoir.

While the production of benthic fauna would probably be enhanced from an enlarge habitat and high nutrient load now existing in the Trinity River, some groups of invertebrates could be reduced. Isom (1971) reported that the benthic fauna in the Tennessee Valley region was limited by siltation, rheotactile deprivation, water level fluctuation, increased hydrostatic pressure, light and most pertinently by hypolimnitic oxygen deficiency in impoundments.

1. Oxygen deficiency

Oxygen concentration is a critical, but a common factor of the profundal zone in a thermally stratified reservoir. Only a few, more tolerant organisms, such as oligochaetes, culicid (Chaoborus), and some chironomids, can survive in this area which approaches anoxia. Other sessile organisms, typical of shallow margins of an impoundment, could be adversely affected if an oxygen deficiency developed at the mud-water interface, causing reduced growth periods or survival of some forms. Jonasson (1969) reported that the number of sessile benthic dwelling organisms may drop to near zero or become restricted to oligochaetes during the final stages of eutrophication.

2. Rooted aquatic plants

The establishment of rooted aquatic plants will probably be limited in the proposed reservoir because of fluctuating water levels and its high turbidity. Some benthic groups, such as odonates, are dependent upon these plants for living space, food, shelter, and attachment sites for reproductive purposes. Hence, the benthic fauna would be more abundant and diverse if macrophytes were established.

3. Position in food web

Bottom fauna are an important link in the food chain of a reservoir and therefore reflect on fish production. However, any one of these forage organisms is not of constant abundance and is ofter cyclic, responding to climatic or environmental conditions which alters their abundance. A limited benthic fauna in the littoral zone of a reservoir has its greatest influence on those fishes classified as grazers. For example, the bluegill (Lepomis macrochirus) feeds along the bottom on a variety of aquatic invertebrates. Also many fish species which prey on other fishes as adults rely on benthic and planktonic organisms as major food items during the early stages of their life history.

Although benthic organisms serve an important role in the food web of a reservoir, a limited fauna may not reflect a poor fishery. Texas reservoirs are typically characterized by a short plankton-to-fish chain. Gizzard shad (Dorosoma cepedianum) and threadfin shad (D. petenense) are the primary forage species and rely on plankton as their primary food source rather than benthic forms.

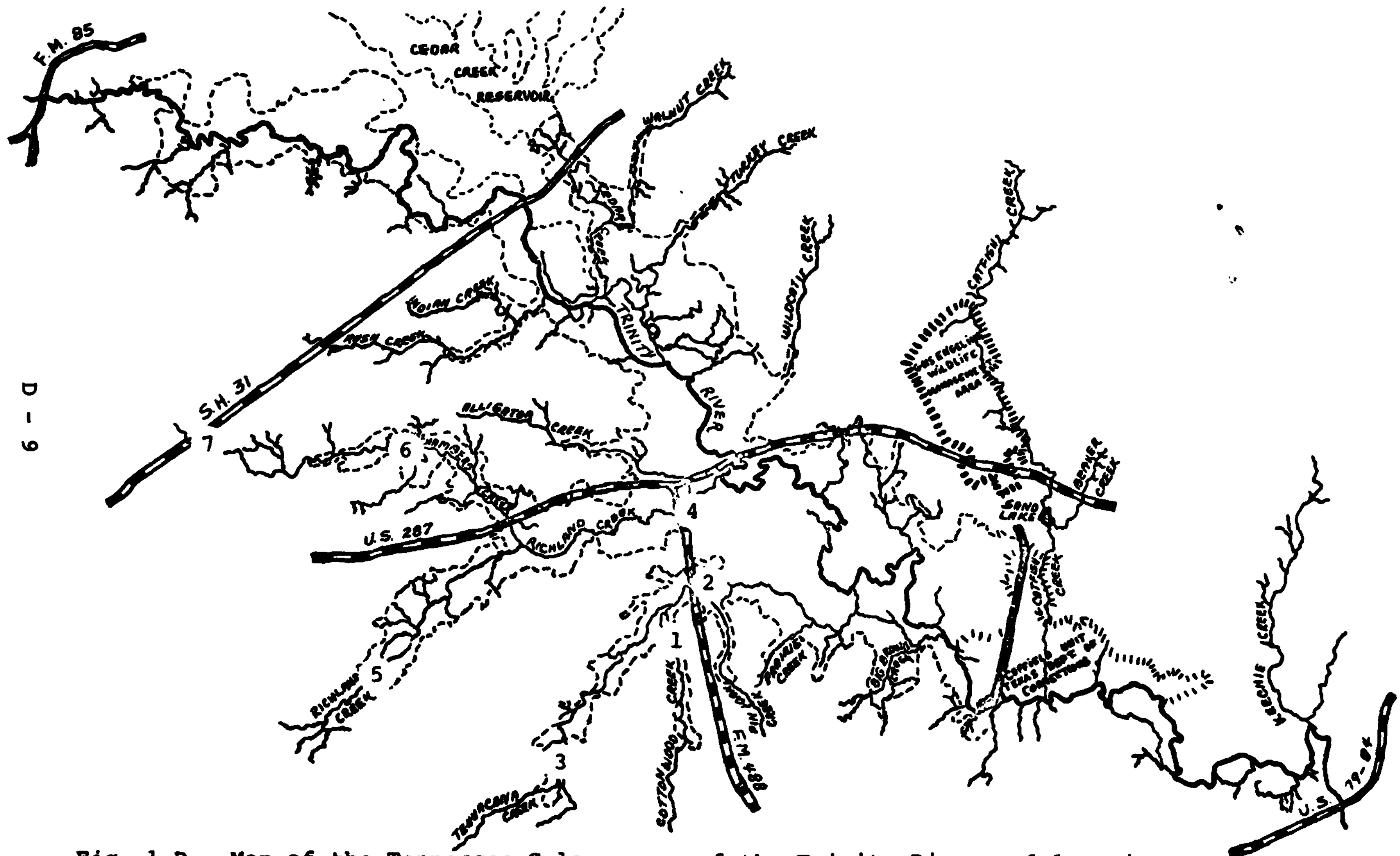

Fig. 1-D. Map of the Tennessee Colony area of the Trinity River and locations of benthic macroinvertebrate sampling stations.

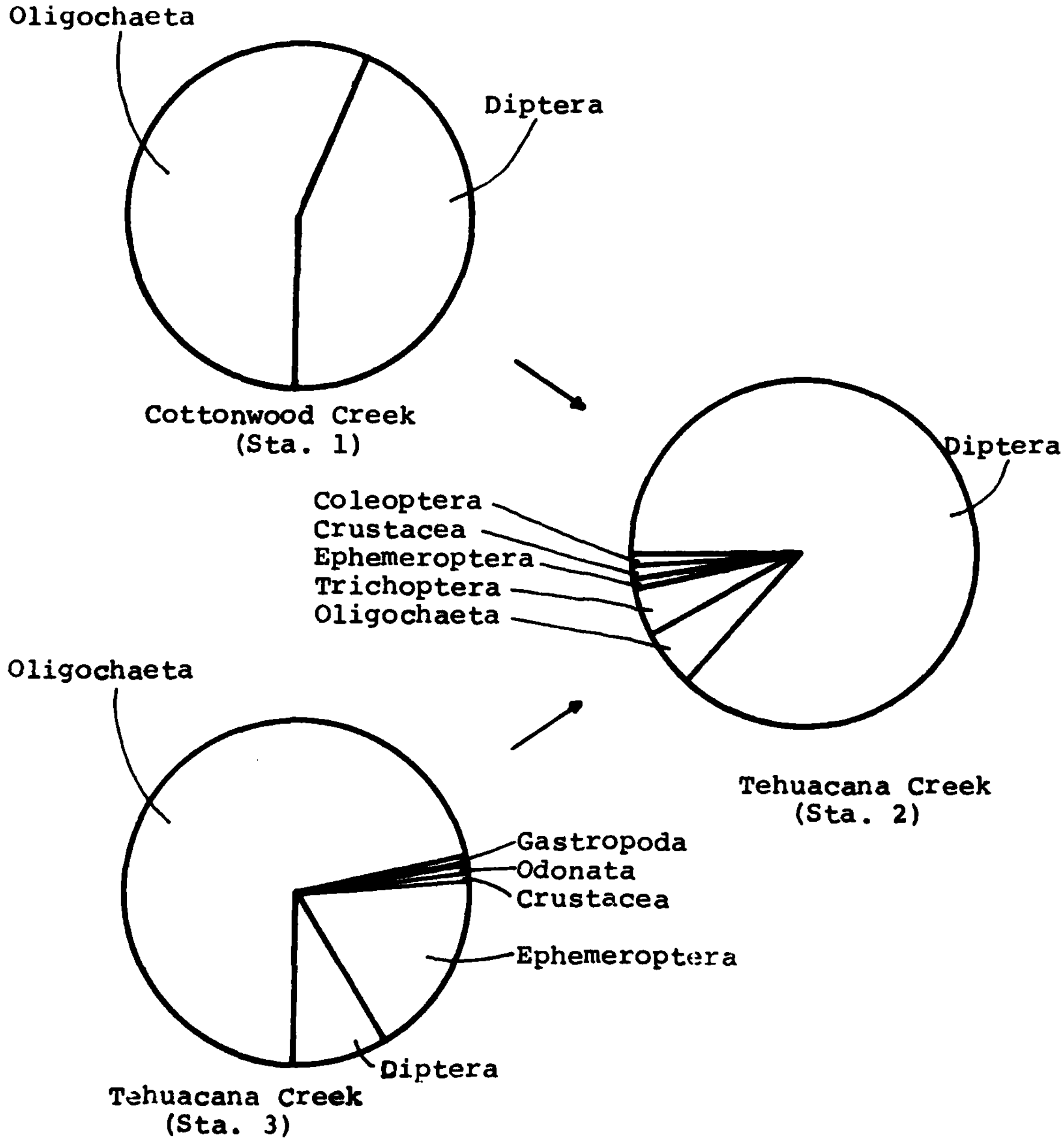

Fig. 2-D. Composition of the bottom fauna of the Trinity River tributaries. (Arrow indicates direction of flow.)

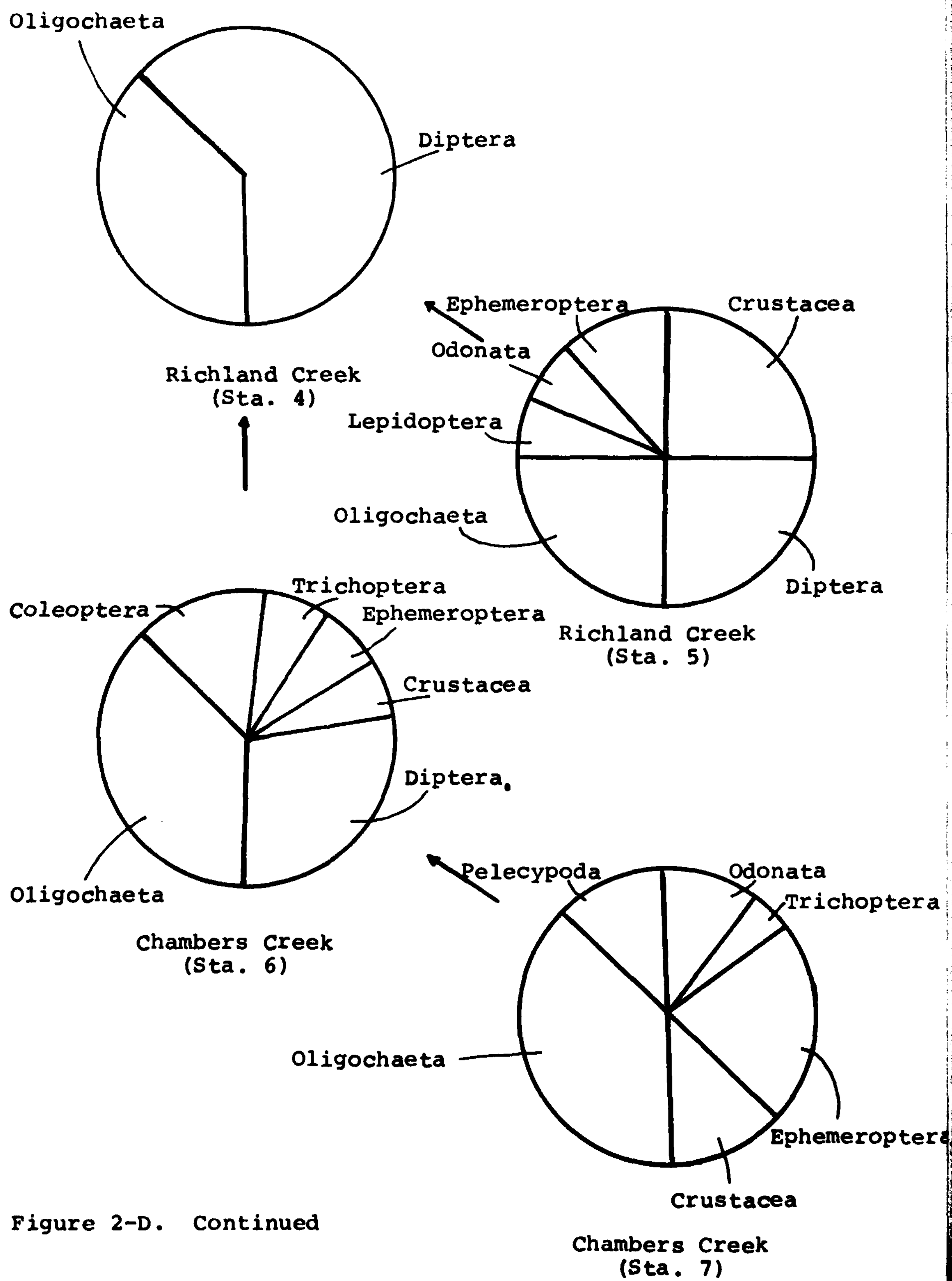

Figure 2-D. Continued

Table 1-D. Relative abundance of benthic macroinvertebrates from the Trinity River tributaries.

	Collecting Stations						
	*1	2	3	4	5	6	7
OLIGOCHAETA							
Lumbriculidae	A		D	F	F	A	A
Tubificidae		O	F	O			
CRUSTACEA							
Gammaridae			R				
Palaeomonidae					F	O	O
EPHEMEROPTERA							
Ephemeridae		O	A				O
Heptageniidae					O	O	F
ODONATA							
Coenagrinonidae			R		O		O
TRICHOPTERA							
Hydropsychidae		O					
Psychomyiidae						O	O
Rhyacophilidae							O
LEPIDOPTERA							
Pyralididae						O	
COLEOPTERA							
Hydrophilidae		R				O	
DIPTERA							
Culicidae	D		O	O		O	
Chironomidae	O	D	F	D	F	F	
Simuliidae		F					
PELECYPODA							
Sphaeriidae						O	
GASTROPODA							
Physidae			O				

D = dominant O = occasional

A = abundant R = rare

F = frequent

*see p. for station locations.

FISHES OF THE TENNESSEE COLONY SITE

A. Habitat change resulting from impoundment

The establishment of a fishery in an impoundment is seldom given top priority but it is almost always a secondary consideration. These considerations should not only be concerned with the commercial and sports fisheries aspects but also the alteration of some fish populations which now may exist either in the river or its tributaries which will be inundated by the construction of the main river dam.

An artificial impoundment reduces flow, resulting in a situation which eventually produces a mud bottom, murky water and will alter a river and its tributaries for many miles upstream. Fishes characteristic of flowing water and firm bottoms are replaced by those characteristic of sluggish water, such as found in oxbows and deep soft-bottom pools, not only in the reservoir but many miles above it.

It is axiomatic that lacustrine fishes may also inhabit the main river channel above the reservoir and smaller tributaries, but a substantially smaller percentage of fish species usually found in small streams with moderate current will succeed in lakes. Fritz (1968) reported on the fish population composition change of the Clinch River, Melton Hill Reservoir area upon impoundment. From a total of 60 species, 35 occurred before and after impoundment, 12 before impoundment only, and 13 after impoundment only. The construction of a large impoundment, like the proposed Tennessee Colony Reservoir, thus provides large-lake niches that can be occupied either by existing fish fauna characteristic of oxbows and backwater areas or by introduced species adapted for this created habitat.

A checklist of fish species which have been reported from the upper Trinity River Basin (Table 2-D) has been primarily taken from investigations by Hubbs (1961) and Lamb (1958). Limited seining and trapping during this study did not produce any additional species. Some species listed may not, at the present time, occur in the immediate Tennessee Colony site but may occur in tributaries, reservoirs, and tailwaters of existing reservoirs, or in the upper Trinity River which may be influenced by the proposed reservoir

1. Small stream species

Fish species which are characteristic of small streams which have a moderate current and a hard bottom will most likely be affected. The following species, if they now exist in the Tennessee Colony area tributaries to be inundated, may either be eliminated or restricted to that unaltered portion of the stream. None of these species, however, are rare or endangered and most have a wide distribution.

Campostoma anomalum	Stone roller
Lepomis megalotis	Longear sunfish
Lepomis punctatus	Spotted sunfish
Percina sciera	Dusky darter
Notropis atrocaudalis	Blackspot shiner
Notropis fumeus	Ribbon shiner
Notropis lutrensis	Red shiner
Notropis umbratilis	Redfin shiner
Notropis venustus	Blacktail shiner
Semotilus atromaculatus	Creek chub

The relative abundance of the above fishes is poorly known, but one species, Notropis lutrensis was the most widely distributed species in the Trinity River watershed, being collected at 30 of the 39 seine stations found by Lamb (1958). It was also the most numerous fish collected. Cross (1967) reported that N. lutrensis is characteristic of streams of intermittent flow and are most numerous where few other kinds of fish occur. The abundance of this species, thus, may indicate a limited fish fauna in many of the Trinity River tributaries.

2. River channel species

Other fish species reported in the Trinity River watershed which are characteristic of the deeper parts of a major river channel where the current is of varying velocity, usually moderate to strong, will probably be largely confined above or below the proposed reservoir. The following species are usually found in a large river habitat.

Carpiodes carpio	River carpsucker
Cycleptus elongatus	Blue sucker
Hybognathus nuchalis	Silvery minnow
Hybopsis aestivalis	Speckled chub
Ictalurus furcatus	Blue catfish
Lepisosteus osseus	Longnose gar
Notropis atherinoides	Emerald shiner
Notropis buchanani	Ghost shiner
Notropis volucellus	Mimic shiner
Pimephales vigilax	Bullhead minnow
Pylodictix olivaris	Flathead catfish

The Trinity River at and above the Tennessee Colony site contains high nutrient levels, highly turbid, and often reduced oxygen concentration which may have eliminated some of the above riverine species. If channelization above the reservoir occurs, many habitats now present will be destroyed. With a loss in the number of available habitats, resulting from channelization, the number of species will be reduced.

3. Sluggish water species

The pattern of an increased populations of some fishes is generally expected following impoundment. These species' natural habitats includes ponds, oxbows, and slough areas of the flood plain. Some of these fishes appear to have an affinity for rooted vegetation and possibly for soft bottom covered with plant detritus. If the shoreline of the Tennessee Colony Reservoir provides for macrophyte growth, the following species would be benefited.

Amia calva	Bowfin
Aphredoderus sayanus	Pirate perch
Chaenobryttus gulosus	Warmouth
Erimyzon oblongus	Creek chubsucker
Erimyzon sucetta	Lake chubsucker
Esox americanus	Redfin pickerel
Etheostoma chlorosomum	Bluntnose darter
Etheostoma gracile	Slough darter
Fundulus notatus	Blackstripe topminnow
Fundulus olivaceus	Blackspotted topminnow
Lepomis symmetricus	Bantum sunfish
Minytrema melanops	Spotted sucker
Notemigonus crysoleucus	Golden shiner

Notropis texanus	Weed shiner
Opsopoedus emiliae	Pugnose shiner

Other species which are generally found in a greater variety of habitats (sluggish water, mian river channels, medium sized creeks, turbid or clear water) are typical of most reservoirs of this region. Therefore, impoundment of the Trinity River at the Tennessee Colony site should reflect an increased production of the following list of species which would benefit by new stagnant and lentic conditions and find here a greatly enlarge environment.

Aplodinotus grunniens	Freshwater drum
Carassius auratus	Goldfish
Cyprinus carpio	Carp
Dorosoma cepedianum	Gizzard shad
Dorosoma petensense	Threadfin shad
Gambusia affinis	Mosquitofish
Ictalurus punctatus	Channel catfish
Ictalurus melas	Black bullhead
Ictalurus natalis	Yellow bullhead
Ictiobus bubalus	Smallmouth buffalo
Labidesthes sicculus	Brook silverside
Lepisosteus oculatus	Spotted gar
Lepomis cyanellus	Green sunfish
Lepomis humilis	Orange spotted sunfish
Lepomis macrochirus	Bluegill

Lepomis microlophis	Redear sunfish
Micropterus punctulatus	Spotted bass
Micropterus salmoides	Largemouth bass
Morone chrysops	White bass
Percina caproides	Log perch
Phenocobius mirabilis	Suckermouth minnow
Pimephales promelas	Fathead minnow
Pomoxis annularis	White crappie
Pomoxis nigromaculatus	Black crappie
Schilbeodes gyrinus	tadpole madtom

Introduced species, in the Dallas-Ft. Worth area, reported by Lamb (1958) included _Astyanax mexicans_, (Mexican tetra), _Moxostoma congestum_, (gray redhorse), and _Lepomis auritus_, (redbreast sunfish). There is little evidence that the Mexican tetra would survice the winter temperatures of this area. The other two species could, however, become established in the Tennessee Colony Reservoir. _Anguilla rostrata_ (American eel) has probably been eliminated from the Trinity River above Lake Livingston. Because of its catadromous requirements for reproduction the dam has served as a migration barrier for recruitment of this species.

B. Fishery potential

The majority of the fish species in the upper portion of the Trinity River Basin, above and including the Tennessee Colony site, are typically riverine, oxbow, or back-water dwellers. These fishes utilize the shelter and semi-stagnant areas of the river to spawn and reproduce. The formation of a reservoir would enlarge and multiply such favorable environments by providing additional food supplies and cover from predators. Within a comparatively short time a new population equilibrium may be reached which would exceed that now existing in the river, hence a fishery potential.

C. Water quality and fishes

While fish are often the focal point of human interest in a river or lake, they are seldom good indicators of eutrophication. Many fish species are secondary consumers, being near the top of a trophic pyrimid, thus, are less affected than other aquatic organisms. Fish are mobile, have widely fluctuating growth and survival rates, and flexible food habits. Although fish have a poor reputation for eutrophic indicators, they are often under close scrutiny and a mass die-off attracts great public attention. The proposed Tennessee Colony Reservoir receives relatively high nutrient loads, high turbidity, and often contains low dissolved oxygen concentrations. Therefore, attention should be focused on the possible chemical and physical effects on fishes (direct and indirect) which presently exist in the Tennessee Colony Reservoir site on the Trinity River.

1. Nutrient enrichment

The common pattern of response of nutrient enrichment upon an aquatic ecosystem is an immediate increase in plant material. In early stages of eutrophication, one of the first apparent changes may be enhanced fish growth. During the initial year or two of an impoundment, game fish reproduction is usually highly successful in the expanding new environment with relatively little significant competition for food and space. But with increased age conditions become more conducive to successful reproduction of competitor species and relatively less favorable to game species. The general trend has been shown to change in the direction of course fish as eutrophication proceeds (Hasler, 1947), although the total weight (standing crop) gradually increases with progressive accumulation of bottom sediments and nutrients (Jenkins, 1957).

2. Oxygen deficiency and toxicity

Although increased eutrophication is associated with greater production, the consequence to fish populations may be detrimental, especially if blue-green algae is abundant, resulting not only in a sharp oxygen deficiency, but may also have direct toxic effect on fish. In a review on the toxic effects of freshwater algae on animals, Ingram and

Prescott (1954) reported that the blue-green algal group have been responsible for mammalian, avarian, and fish deaths through some toxic action. Often when deaths of animals occur, a wind has been reported which tended to concentrate algae in lee-shore areas. Increase algae growth is a common frustration associated with pond fertilization (Smith and Swingle, 1939; Bennett, 1952; Krumholz, 1952; Saila, 1952).

Characteristic of many organic, nutrient-rich pollutants is their high immediate oxygen demand. The lethal effects of such pollutants on fish is substantially documented in the literature. The effects are especially lethal when these pollutants are discharged in large quantities into streams (Hynes, 1960; Jones, 1964). The Dallas-Ft. Worth area has long been recognized as a heavy contributor to organic loading of the Trinity River, resulting in what locally is termed "black rises" causing massive fish die-offs, presumably from oxygen depletion.

Several studies have indicated that the dissolved oxygen concentration requirement for a fish species is poorly understood. Doudoroff and Shumway (1967) emphasized that growth and embryonic development and the activity of fish can be limited by the oxygen supply but the oxygen requirement is also dependent upon the amount of food available, and other environmental factors, such as temperature. Diel fluctuations in oxygen concentrations may also depress feeding and growth of fish. When low oxygen levels are not lethal, they may influence the vigor of fish and so effect competition between species (Davidson, et al., 1959). For a healthy warm-water fish population it would appear from review of the literature that dissolved oxygen levels should not be below 5 ppm. The recommendation of FWPCA (Anon., 1968) considered essential for maintaining native fish populations and other aquatic life which pertains to warm water lakes (excluding the hypolimnion) includes (1) daily dissolved oxygen concentration above 5 mg/l, assuming there are normal seasonal and daily variations above this concentration, (2) dissovled oxygen may range between 5 mg/l and 4 mg/l for short periods of time, provided that the water quality is favorable in all other respects, and (3) in shallow unstratified lakes, they should apply to the entire circulating water mass.

The selected chemical and biochemical records of Texas surface waters, 1970, of USGS indicated that the dissolved oxygen concentration during the late spring to early fall months is below the minimum guidelines established by FWPCA in much ov the Trinity River above the proposed reservoir. Although impoundment will most likely elevate the dissolved oxygen level because of the greater surface area to which the water mass will be exposed, the upper end of the reservoir may be continually below a satisfactory oxygen level for warm water fishes.

Toxic compounds associated with municipal and industrial effluents may have a direct toxic effect or may be enhanced at reduced oxygen concentrations (Allan et al., 1958). One such toxic compound which is well known is ammonia. Doudoroff and Katz (1950) cite numerous investigastions giving results of lethal concentrations of ammonia around 2 to 7 ppm with the highest ranging around 25 ppm as NH_3. Shad, sunfish, and catfishes were found to be among the most susceptible species in experimental ponds treated with 13 to 40 ppm of anhydrous ammonia (Klaussmann, et al., 1969). The toxic effect of ammonia may be more profound if the dissolved oxygen level is low since one of the symptoms of ammonia toxicity is depressed respiration (Belding, 1927).

Ammonia nitrogen concentrations recorded from the Trinity River at Trinidad, Texas (USGS selected chemical and biochemical records of Texas surface waters, 1970) reached 13 ppm in December, 1969 and ranged from 0.52 to 8.6 ppm from June 1970 through September, 1970. During the summer months dissolved oxygen was lower (1.9 to 4.4 ppm) than the cooler months. Under these adverse conditions the area would be uninhabitable for many fish species. The dilution factor should reduce the possible toxicity by ammonia in a reservoir, but the water entering the reservoir may continue to be somewhat toxic. Because fish are mobile, they may respond to such an adverse environment by moving from the scene into a more optimum habitat.

3. Turbidity

Turbidity is caused by the presence of suspended matter such as clay, silt, finely divided organic matter, bacteria, plankton, and other microscopic organisms. These suspended particles cause light rays to be scattered and absorbed rather than transmitted in a straight line and may exert an indirect effect on the aquatic environment through light exclusion.

Turbidity data, usually give in Jackson Turbidity Units, are lacking from existing records of the Trinity River at the Tennessee Colony site except of Secchi disc readings (Table E-1). These readings indicate a highly turbid condition presently existing at the proposed reservoir site. Although large variations in turbidity occur naturally, it is often aggravated by man's activities.

Channelization above the reservoir might therefore result in increased turbidity entering the reservoir by erosion of the cleared banks.

The effect of high turbidity on fish is largely an indirect action. In nature turbidities are not found high enough to have a direct effect and the indirect effects are varied in their actions. Buck (1956) showed a decrease in fish production with increasing turbidity and probably indirectly responsible for the disappearance of certain species. Reduction in temperature and light penetration effects plankton productivity and tends to reduce total stream productivity (Wallen, 1951) causing scarcity of certain foods (Starrett, 1950) and reducing the diversity of benthic macroinvertebrates (Rainwater, 1969). Siltation of spawning beds has accounted for reduction in abundance and elimination of certain fish species and habitat of many aquatic insects and other invertebrate animals such as mollusks, crayfish, freshwater shrimp, etc., which serve as food items for many fish species. Reduced bottom fauna caused by silting has been investigated by Tarzwell (1957) and Smith (1940). Many game fish feed by sight. In turbid waters they are at increased disadvantage when competing with "rough" fish which employ a vacuum-cleaner type of feeding behavior (i. e., carp, buffalo, and carpsuckers). High turbidity can, therefore, bring about both quantitative as well as qualitative changes in the fish fauna.

The recommendation of FWPCA is that no discharge into warm-water lakes which cause turbidities exceeding 25 Jackson Units and receiving water due to a discharge should not exceed 50 JTU in warm-water streams. Although JTU measurements are unavailable for the Tennessee Colony area the transparency of the water is very restricted as indicated by very low Secchi disc readings. Therefore, the receiving water from the reservoir will probably exceed the recommended level which will have an adverse affect on the aquatic organisms attempting to occupy this area.

Table 2-D. Checklist of fish species reported from the upper Trinity River Basin, including the Tennessee Colony Area.

Scienfitic Name	Common Name
Lepisosteidae	
Lepisosteus oculatus	Spotted gar
Lepisosteus osseus	Longnose gar
Amiidae	
Amia calva	Bowfin
Clupeidae	
Dorosoma cepedianum	Gizzard shad
Dorosoma petenense	Threadfin shad
Esocidae	
Esox americanus	Redfin pickerel
Characidae	
Astyanax mexicanus	Mexican tetra
Catostomidae	
Carpiodes carpio	River carpsucker
Cycleptus elongatus	Blue sucker
Erimyzon oblongus	Creek chubsucker
Erimyzon sucetta	Lake chubsucker
Ictiobus bubalus	Smallmouth buffalo
Ictiobus niger	Black buffalo
Minytrema melanops	Spotted sucker
Moxostoma congestum	Gray redhorse
Cyprinidae	
Campostoma anomalum	Stoneroller

Table 2-D Continued

Carassius auratus	Goldfish
Cyprinus carpio	Carp
Hybognathus nuchalis	Silvery minnow
Hybopsis aestivalis	Speckled chub
Notemigonus crysoleucas	Golden shiner
Notropis atherinoides	Emerald shiner
Notropis atrocaudalis	Blackspot shiner
Notropis buchanani	Ghost shiner
Notropis fumeus	Ribbon shiner
Notropis lutrensis	Red shiner
Notropis texanus	Weed shiner
Notropis umbratilis	Redfin shiner
Notropis venustus	Blacktail shiner
Notropis volucellus	Mimic shiner
Opsopoeodus emiliae	Pugnose shiner
Phenocobius mirabilis	Suckermouth minnow
Pimphales promelas	Fathead minnow
Pimphales vigilax	Bullhead minnow
Semotilus atromaculatus	Creek chub
Ictaluridae	
Ictalurus furcatus	Blue catfish
Ictalurus melas	Black bullhead
Ictalurus natalis	Yellow bullhead
Ictalurus punctatus	Channel catfish
Pylodictus olivaris	Flathead catfish
Schilbeodes gyrinus	Tadpole madtom

Table 2-D Continued

Anguillidae	
Anguilla rostrata	American eel
Cyprinodontidae	
Fundulus notatus	Blackstripe topminnow
Fundulus olivaceus	Blackspotted topminnow
Poeciliidae	
Gambusia affinis	Mosquito fish
Aphredoderidae	
Aphredoderus sayanus	Pirate perch
Atherinidae	
Labidesthes sicculus	Brook silverside
Perichthyidae	
Morone chrysops	White bass
Centrarchidae	
Chaenobryttus gulosus	Warmouth
Lepomis auritus	Redbreast sunfish
Lepomis cyanellus	Green sunfish
Lepomis humilis	Orangespotted sunfish
Lepomis macrochirus	Bluegill sunfish
Lepomis megalotis	Longear sunfish
Lepomis microlophus	Redear sunfish
Lepomis punctatus	Spotted sunfish
Lepomis symmetricus	Bantam sunfish
Micropterus punctulatus	Spotted bass
Micropterus salmoides	Largemouth bass
Pomoxis annularis	White crappie

Table 2-D Continued

Pomoxis nigromaculatus	Black crappie
Percidae	
Etheostoma chlorosomum	Bluntnose darter
Etheostoma gracile	Slough darter
**Percina caprodes*	Log perch
Percina sciera	Dusky darter
Sciaenidae	
Aplodinotus grunniens	Freshwater drum

*described as a new species, *Percina macrolepida*, by Stevenson (1971) occurring in the upper Trinity River.

AMPHIBIANS AND REPTILES OF THE TENNESSEE COLONY SITE

A. Habitat change resulting from impoundment

The amphibian and reptilian fauna occuring the Tennessee Colony area is based on the herptile distribution studies of Brown (1950), Conant (1958), and Cochran and Goin (1970). Some of the species or subspecies listed (Table 3-D) may be absent from the immediate area and their abundance in the area to be impounded is unknown. Certainly changes in the populations of this group will result from the filling of the reservoir, but its extent will depend upon; (1) extent of terrestrial areas not flooded which now serve as suitable habitat for some species (2) extent of shallow vegetated shoreline for some species and (3) abundance of food items in the modified environment.

1. Bottomland forest floor species

The greatest impact of the proposed reservoir on the populations of amphibians and reptiles will be the elimination of habitat provided by the now existing bottomland vegetation which would be inundated. Some of the herptile species now occurring in this bottomland area will be forced to emigrate into areas which may or may not be favorable to their survival. The majority of animals affected are dependent upon the moist bottomland forest floor, with its rotting logs, shrubs, and food items afforded within this habitat. The following species will be pushed from their habitat when the reservoir fills. None of the species listed from the area are endemic and most are widely distributed throughout eastern Texas and adjacent states north and east.

Salamanders	
Ambystoma opacum	Marbled salamander
Ambystoma texanum	Small-mouthed salamander
Ambystoma tigrinum	Tiger salamander
Manculus quadridigitatus	Dwarf salamander
Notophthalmus viridescens	Central newt
Frogs	
Hyla cinera	Green treefrog
Hyla chrysoscelis	Gray treefrog
Pseudacris clarki	Spotted chorus frog
Pseudacris streckeri	Strecker's chorus frog
Pseudacris triseriata	Upland chorus frog
Rana areolata	Crawfish frog
Rana clamitans	Bronze frog
Turtles	
Terrapene carolina	Box turtle
Lizards	
Anolis carolinensis	Carolina anole

Eumeces faciatus	Five-lined skink
Eumeces laticeps	Broad headed skink
Eumeces septentrionalis	Prairie skink
Sceloporus undulatus	Fence swift
Lygosoma laterale	Ground skink

Snakes

Agkistrodon contortrix	Copperhead
Crotalus horridus	Canebrake rattlesnake
Diadophis punctatus	Ringneck snake
Masticophis flagellum	Coachwhip snake
Micrurus fulvius	Coral snake
Opheodrys aestivus	Rough green snake
Sisturus miliaris	Pigmy rattlesnake
Storeria dekayi	Dekay's brown snake
Tantilla gracilis	Fatheaded snake

2. Flowing water species

Other species will be forced to move from the impounded water into an area of continuous flow, either the river channel or its tributaries. The following are species of this area characteristic of a flowing water habitat.

Salamanders

Siren intermedia	Lesser siren

Turtles

Chrysemys concinna	Slider

Malaclemys kohni — Mississippi map turtle

Trionyx muticus — Smooth softshell turtle

Trionyx spiniferus — Spiny softshell turtle

3. Shoreline species

The proposed reservoir will greatly increase the shoreline and therefore provide a habitat characteristic of several species of amphibians and reptiles. The following list of species will probably benefit from the shallow, vegetated still water with a soft bottom resulting from impoundment and the creation of many marginal areas within the reservoir.

Frogs

Rana catesbeiana	Bullfrog
Acris crepitans	Cricket frog

Turtles

Chelydra serpentina	Common snapping turtle
Chrysemys scripta	Red eared turtle
Deirochelys reticularia	Chicken turtle
Kinosternon flavescens	Yellow mud turtle
Kinosternon subrubrum	Mud turtle
Macroclemys temmincki	Alligator snapping turtle
Sternothaerus carinatus	Keel-backed musk turtle
Sternothaerus odoratus	Stinkpot

Snakes

Agkistrodon piscivorus	Cottonmouth

Farancia abacura	Mud snake
Natrix erthrogaster	Plain bellied water snake
Natrix rhombifera	Diamondbacked water snake
Regina grahami	Graham's water snake
Regina rigida	Glossy water snake
Thamnophis marcianus	Checkered garter snake
Thamnophis sirtalis	Common garter snake

B. Species not affected by impoundment

Other species of herptiles listed in Table 3-D have either a variety of habitat types or they are generally associated with an upland or more open environment which will not be inundated by the reservoir.

Table 3-D. Check list of amphibians and reptiles reported from the upper Trinity River Basin, including the Tennessee Colony Area.

Scientific Name	Common Name
Amphibia	
Sirenidae	
Siren intermedia nettingi	Western lesser siren
Ambystomatidae	
Ambystoma opacum	Marbled salamander
Ambystoma texanum	Small-mouthed salamander
Ambystoma tigrinum tigrinum	Eastern tiger salamander
Salamandridae	
Notophthalmus viridescens louisianensis	Central newt
Plethodontidae	
Manculus quadridigitatus	Dwarf salamander
Pelobatidae	
Scaphiopus couchi	Couch's spadefoot toad
Scaphiopus hurteri	Hurter's spadefoot toad
Ranidae	
Rana areolata areolata	Southern crawfish frog
Rana catesbeiana	Bull frog
Rana clamitans clamitans	Bronze frog
Rana pipens berlanderi	Rio Grande leopard frog

Table 3-D Continued

Microhylidae	
Gastrophryne olivacea olivacea	Great Plains narrow mouthed frog
Bufonidae	
Bufo speciosus	Texas toad
Bufo valliceps	Gulf Coast toad
Bufo woodhousei woodhousei	Rocky Mt. toad
Hylidae	
Acris crepitans crepitans	Northern cricket frog
Hyla cinera cinera	Green tree frog
Hyla chrysoscelis	Gray tree frog
Pseudacris clarki	Spotted chorus frog
Pseudacris streckeri streckeri	Strecker's chorus frog
Pseudacris triseriata feriarum	Upland chorus frog
Reptilia	
Chelydridae	
Chelydra sepentina	Common snapping turtle
Macroclemys temmincki	Alligator snapping turtle
Kinosternon flavescens flavescens	Yellow mud turtle
Kinosternon subrubrum hippocrepis	Mississippi mud turtle
Sternothaerus carinatus	Keel-backed musk turtle

Table 3-D Continued

Chelydridae continued	
Sternothaerus odoratus	Stinkpot
Testudinidae	
Chrysemys concinna texana	Texas slider
Chrysemys scripta elegans	Red eared turtle
Deirochelys reticularia miaria	Western chicked turtle
Malaclemys kohni	Mississippi map turtle
Terrapene carolina major	Gulf Coast box turtle
Terrapene carolina triunguis	Three-toed box turtle
Terrapene ornata ornata	Ornate box turtle
Trionchidae	
Trionyx muticus muticus	Mississippi smooth soft shell
Trionyx spiniferus emoryi	Texas softshell
Iquanidae	
Anolis carolinensis carolinensis	Carolina anole
Phrynosoma cornutum	Texas horned lizard
Sceloporus olivaceus	Texas spiny lizard
Sceloporus undulatus hyacinthinus	Northern fence lizard
Scincidae	
Eumeces brevilineatus	Short-lined skink
Eumeces fasciatus	Five-lined skink
Eumeces laticeps	Broad headed skink

Table 3-D Continued

Scincidae continued	
Eumeces septentrionalis obtusirostris	Southern prairie skink
Lygosoma laterale	Ground skink
Teiidae	
Cnemidophorus gularis	Texas spotted whiptail
Cnemidophorus sexlineatus sexlineatus	Six-lined race runner
Anguinidae	
Ophisaurus attenuatus attenuatus	Western glass lizard
Colubridae	
Coluber constrictor flaviventris	Easter yellow-bellied racer
Diadophis punctatus arnyi	Prairie ringneck snake
Elaphe guttata emoryi	Great Plains rat snake
Elaphe obsoleta lindheimeri	Texas rat snake
Farancia abacura reinwardti	Western mud snake
Heterodon nasicus gloydi	Dusky hognose snake
Heterodon nasicus nasicus	Plains hognose snake
Heterodon platyrhinos	Eastern hognose snake
Hypsiglena torquata texana	Texas night snake

Table 3-D Continued

Colubridae continued

Lampropeltis calligaster calligaster	Prairie king snake
Lampropeltis getulus holbrooki	Speckled king snake
Lampropeltis triangulum amaura	Louisiana milk snake
Masticophis flagellum flagellum	Eastern coachwhip
Masticophis flagellum testaceus	Western coachwhip
Natrix erythrogaster flavigaster	Yellow-bellied water snake
Natrix erythrogaster transversa	Blotched water snake
Natrix rhombifera rhombifera	Diamond backed water snake
Opheodrys aestivus	Rough green snake
Pituophis melanoleucus sayi	Bull snake
Regina grahami	Graham's water snake
Regina rigida sinicola	Gulf Coast water snake
Storeria dekayi texana	Texas brown snake
Tantilla gracilis gracilis	Slender flat headed snake
Thamnophis marcianus marcianus	Eastern checkered garter snake

Table 3-D Continued

Colubridae continued	
Thamnophis sirtalis annectens	Texas garter snake
Tropidoclonion lineatum annectens	Central lined snake
Tropidoclonion lineatum texanum	Texas lined snake
Virginia striatula	Rough earth snake
Virginia valeriae elegans	Western earth snake
Elapidae	
Micrurus fulvius tenere	Texas coral snake
Viperidae	
Agkistrodon contortrix contortrix	Southern copperhead
Agkistrodon contortrix laticinctus	Broad-banded copperhead
Agkistrodon piscivorus leucostoma	Western cottonmouth
Crotalus atrox	Western diamondback snake
Crotalus horridus atricaudatus	Canebrake rattlesnake
Sistrurus catenatus tergeminus	Western massasauga

Table 3-D Continued

Viperidae continued	
Sistrurus miliarius streckeri	Western pigmy rattle-snake
Crocodylidae	
Alligator mississipiensis	American alligator

AVIAN AND MAMMALIAN FAUNAS OF THE TENNESSEE COLONY AREA

(by Dr. Charles D. Fisher)

A. Present composition of the faunas.

1. Overall diversity and relative abundance

The North American continent north of Mexico has been divided into 25 biotic provinces by Dice (1943). Blair (1950) has revised slightly the provinces of Dice for the state of Texas. Because of its size and unique geographical position on the continent, Texas lies in 7 of the 25 biotic provinces. Each province is a continuous geographic area within which ecological associations tend to be of a similar nature.

Tennessee Colony is situated on 95°50'W longitude, between the Texan and Austroriparian biotic provinces. The Austroriparian province extends all the way from east Texas eastward across southeastern United States to the Atlantic Ocean, and is characterized by forests of pine and hardwoods. It contains numerous swamps and marshes. The Texan province, on the other hand, is much smaller in size, forming a rather narrow north-south belt between the forests of east Texas and the prairies of central Texas. It is thus a broad ecotone with prairies on the upland clay soils and hardwood forests on the creek and river bottoms. As in the Austroriparian, winters are short and mild, and summers are long and hot. Rainfall is considerable in both provinces, but is less in the Texan than in the Austroriparian. Blair (1950) remarks that of 49 species of mammals in the Texan province, 41 also occur in the Austroriparian. The avian and mammalian faunas of the Tennessee Colony area are therefore closely associated with the birds and mammals of the southeastern United States. However, a few grassland species typical of the central Texas prairie regions are also present.

a. Birds--Table D-4 lists a total of 259 species of birds known to occur regularly in the Tennessee Colony area. Species of accidental occurrence have been omitted. Data were obtained by me in the field in the Tennessee Colony area from September through November, 1971. In addition, published records were taken from past issues of "Audubon Field Notes" (now called "American Birds"), the A. O. U. Checklist of North American Birds (5th ed., 1957), and Peterson (1960). Mr. O. C. Sheffield of Tyler and Mr. Edward C. Fritz of Dallas kindly allowed me use of some of their unpublished field notes.

The Tennessee Colony area is the westernmost extension of the breeding range in the United States of such forest inhabiting birds as the Wood Duck, Chuck-will's-widow, Acadian Flycatcher, Wood Thrush, Prothonotary Warbler, Swainson's Warbler, Louisiana Waterthrush, Kentucky Warbler, and Hooded Warbler. These species are all restricted primarily to bottomland hardwood forests in the vicinity of streams and swamps (see particularly Meanly, 1971; Griscom, et. al., 1957). Bottomland forests in the Tennessee Colony area also provide suitable habitat for a great variety of small songbirds, such as flycatcher, thrushes, wrens, vireos, and warblers, during spring and fall migrations. In the wintertime the American Woodcock reaches the western edge of its range in this area, frequenting the borders of wooded swamps and sloughs. The Harris' Sparrow, a species which winters in the southern great plains region, reaches its easternmost point of abundance in this part of the state, inhabiting thickets, weedy fields, and woodland edges.

The Tennessee Colony area is situated on the eastern edge of the "Central Flyway" for North American waterfowl (Kortright, 1942). This flyway is one of four principal North American migratory routes used by waterfowl, and by other birds as well, in moving between northern breeding grounds and more southerly wintering regions. Although waterfowl are not as common in the Tennessee Colony area as they are farther west in central Texas nearer the middle of the flyway, the area is nevertheless an important one for these birds, being used both during migration and throughout the winter months. The swamps, marshes, and sloughs in the Trinity River floodplain and along many of the creeks provide excellent food and cover, and ducks are widespread in winter throughout the area. However, concentrations are not as great as along the coast or in many other inland localities.

Of particular importance to the area are Cedar Creek and Big Brown reservoirs, and also the small lake at the Trinidad power plant. These open bodies of water are used extensively by many kinds of migratory water birds, such as loons, grebes, ducks, geese, pelicans, cormorants, coots, gulls, and terns. They are also frequented by the Osprey and Bald Eagle, two American species now on the endangered list, and by large wading birds such as herons, egrets, and ibises. My observations lead me to suspect that certain species of birds formerly confined almost entirely to the Texas coast may be occurring at inland localities now much more regularly than in the past, as a result of the creation of such artificial bodies of water. Species typical of coastal Texas which I recorded on Cedar Creek Reservoir include the Mottled Duck, Wood Ibis, Laughing Gull, Common Tern, and Caspian Tern.

The swamps, sloughs, and oxbow lakes in the Tennessee Colony area provide excellent habitats for nesting herons and egrets. A large heronry at Sand Lake northwest of Palestine near the junction of Beaver and Catfish creeks is particularly noteworthy. Mr. O. C. Sheffield (pers. comm.) reports that about 4,000 to 5,000 birds nest here, approximately three-fourths being Cattle Egrets. Other nesting species include the Anhinga, Great Blue Heron (a few), Green Heron, Little Blue Heron, Common Egret, Snowy Egret, Black-crowned Night Heron, and possibly the White Ibis (a few individuals having been seen during the summer). This heronry is thus one of the more important nesting sites for large wading birds in eastern Texas. Sand Lake is relatively inaccessible by boat, owing to very dense woody vegetation in the lake, and the nesting colony is therfore in no immediate danger from human disturbance. The lake is on private property which is kept locked, and although a private hunting club uses the area for deer hunting in the fall and winter, herons and egrets are not present at this time of year. The property owner, Mr. T. K. Royall, is anxious to protect the heronry.

The Gus Engeling Wildlife Management Area about 18 miles northwest of Palestine on Highway 287 encompasses nearly 11,000 acres of post oak and bottomland woodlands, with several large marshy areas. It is drained by Catfish Creek. According to Mr. E. Davis, herons and egrets nested in the area in 1969 but not in 1970 or 1971. However, the marshes are important feeding and roosting areas for a large number of waterfowl during the winter months. Because of the variety of habitat and its protected nature, Engeling is of major importance as a breeding area for many kinds of birds, and is equally important as a stopping place for migrating song birds during spring and fall migration periods. Included among the birds which I recorded in this area on Sept. 16 and 17, 1971, were Cooper's Hawk, Barred owl, Yellow-billed Cuckoo, Pileated Woodpecker, Red-headed Woodpecker, E. Wood Pewee, Olive-sided Flycatcher, Acadian Flycatcher, Crested Flycatcher, Blue-gray Gnatcatcher, White-breasted Nuthatch, Yellow-throated Vireo, Parula Warbler, Hooded Warbler, Summer Tanager, and Indigo Bunting.

b. Mammals--The 43 kinds of mammals known to inhabit the Tennessee Colony area are listed in Table D-5. Species which formerly inhabited the area but for which there are no authentic recent records, such as Ursus americanus, Cania rufus, and Felis concolor, have been omitted. In estimating relative abundance I have taken into consideration both size and ecological niche of the various species. Thus the coyote (Canis latrans), gray squirrel (Sciurus carolinensis), and white-footed mouse (Peromyscus leucopus) are all here considered "common", although their actual population densities are not of the same magnitude. Estimates of relative abundance also reflect conspicuousness, and ease of capture of the species involved. Large species and those with diurnal habits are more apt to be recorded than small, nocturnal, or shy mammals. For example, the apparent abundance of the plains pocket gopher (Geomys bursarius) may be due in part to the conspicuous mounds built by this fossorial animal. In spite of these difficulties, it is felt that the relative abundance data presented are of value in conveying an estimate of mammalian population sizes in the Tennessee Colony area. Data were compiled from my own field notes, from information supplied to me in interviews with Mr. Walt Daniel of Fairfield, Mr. Jack W. Rogers of Palestine, and Mr. E. Davis of the Gus Engeling Wildlife Management Area, from unpublished field notes kindly loaned to me by Dr. David J. Schmidly of Texas A & M University, and from published records of W. B. Davis (1966) and McCarley (1959).

Forest species of mammals which reach the western limit of their range in the Tennessee Colony area are the short-tailed shrew (Blarina brevicauda), evening bat (Nycticeius humeralis), Florida freetail bat (Tadarida cynocephala), swamp rabbit (Sylvilagus aquaticus), eastern gray squirrel (Sciurus carolinensis), cotton mouse (Peromyscus gossypinus), and golden mouse (Peromyscus nuttalli). Prairie species which extend as far east as the Tennessee Colony area include the blacktail jackrabbit (Lepus californicus), thirteen-lined ground squirrel (Citellus tridecemlineatus), and deer mouse (Peromyscus maniculatus). In addition, the ringtail cat (Bassariscus astutus), a mammal of semi-arid rocky areas in southwestern Texas, occurs uncommonly as far east in the state as the Tennessee Colony area.

Of particular significance is the abundance of beavers (Castor canadensis) in the Tennessee Colony area. According to Mr. Daniel Lay of the Texas Parks & Wildlife Dept. (per. comm.) beavers were first introduced into Anderson, Henderson, Navarro, and Freestone Counties about 1939 or 1940 from populations in West Texas along the Red and Llanos rivers. Since this time they have thrived in the Tennessee Colony area and are now one of the most conspicuous mammals of the area, inhabiting almost all the creeks of the area and the Trinity River itself. Many beaver dams and their associated ponds can be seen from roads and highways. In addition to constructing the familiar domed houses of sticks in ponds and marshes, beavers also utilize the steep banks of the river and larger creeks in the area for tunneling and building dens. I did not visit a single creek or a single stretch of the river without seeing either old or recent beaver activity. The creeks on which beavers were found, either by me or by Dr. E. S. Nixon, are Chambers, Richland, Indian, Rush, Prairie, Cottonwood, Keechie, Catfish, Beaver, Cedar, and Wildcat. Beavers were particularly common along the river between Highways 31 and 287, where numerous individuals were seen along the banks in the daytime by observers travelling down the river in a boat. I know of no other locality in Texas where beavers are presently as abundant as in the Tennessee Colony area. They are apparently completely absent from most of east Texas, and I am not aware of their occurrence on any of the streams in the Sabine, Attoyac, Angelina, or Neches watersheds. Their presence and abundance in the Trinity watershed is therefore worthy of special mention. In this regard, it is noteworthy that I found virtually no recent beaver activity on the upper end of Cedar Creek Reservoir, although there was evidence that beavers had once inhabited the creeks there prior to their inundation. On the other hand, nutrias (Myocastor coypus) were conspicuous and common in the marshes at the upper end of the reservoir.

2. Species of economic importance.

There is a good variety of game animals in the Tennessee Colony area, and hunting is a popular sport. Hunting leases bring income to many landowners in the area. The most popular game animals are the white-tailed deer (Odocoileus virginianus), fox (Sciurus niger), and gray squirrels, Mourning Doves, Bobwhites, and waterfowl. To a lesser extent the following species are also hunted: eastern cottontail (Sylvilagus floridanus), swamp rabbit, raccoon (Procyon lotor), red fox (Vulpes fulva), Common Snipe, American Woodcock, and Turkey. The best habitats for most of these game species are the bottomland hardwood forests and the swamps, marshes, sloughs, and oxbow lakes on the creek and river floodplains. Eastern cottontails, Mourning Doves, and Bobwhites are primarily upland game species, but these animals receive less attention from hunters in the Tennessee Colony area than do forest species and waterfowl. The white-tailed deer is perhaps the most popular of all the game animals in the area, and population densities in favorable habitats reach 1 deer to 20 or 25 acres, or rarely 1 deer to 10 acres, as on the Coffield State Prison Farm (Walt Daniel, per. comm.).

Although both beaver and mink (Mustela vison) have commercially valuable pelts, there is little trapping activity for these two mammals in the Tennessee Colony area at the present time. Since both species are relatively common, this lack of interest by trappers appears to be a result primarily of poor prices for east Texas pelts, and a general decline in the trapping of wild fur-bearing animals throughout the country because of competition from animals grown and bred in captivity on commercial fur farms, as well as competition from synthetic fibers. With the increase in numbers of nutria in the area it is possible that this species might have limited commercial value as a fur-bearing animal (See Palmer, 1957).

3. Rare or endangered species.

There are no rare or endangered mammals in the Tennessee Colony area. The black-footed ferret (*Mustela nigripes*) is a prairie species which formerly occurred in the northern and western portions of the state, usually in close association with the black-tailed prairie dog (*Cynomys ludovicianus*). However, the range of the ferret, now perhaps extinct in Texas, never extended as far east as the Trinity River. The red wolf (*Canis rufus*) formerly inhabited east Texas, but there are no recent reliable records from this part of the state, and the species now appears to be confined to the upper coastal plain.

No rare or endangered birds breed in the Tennessee Colony area. However, three species considered rare or endangered migrate through this part of Texas, and sometimes winter here. These are the Bald Eagle, Peregrine Falcon, and Osprey. All three birds are generally associated with large bodies of water such as lakes, reservoirs, rivers, and coastal bays and estuaries. The Bald Eagle and Osprey are principally fish eating species, whereas the Peregrine Falcon feeds primarily on small to large birds, often waterfowl, which are taken on the wing. All three species probably owe their decline, in part, to direct or indirect effects of pesticides, specifically DDT and related chlorinated hydrocarbons, in their body tissues. In the Tennessee Colony area the Bald Eagle and Osprey have been seen at both Cedar Creek and Big Brown reservoirs. I suspect that they are fairly regular migrants and winter visitants, in very small numbers, to these bodies of water. It is possible that the Bald Eagle could breed in the area, but I know of no recent nests from this part of the state.

There is no evidence that the Ivory-billed Woodpecker presently occurs anywhere along the Trinity River, though it may formerly have done so. It is extremely doubtful if this species persists anywhere in the state of Texas today. The Red-cockaded Woodpecker, another endangered species, is locally distributed in the pine woodlands of east Texas, where in some areas it is not uncommon. However, suitable pine forests are not present in the Tennessee Colony area, and the species is therefore absent.

B. Environmental impact and predicted population changes.

A reservoir will be created with a maximum surface area of roughly 150,000 acres if a dam is constructed at site 2A on the Trinity River. The area to be inundated will be the Trinity River floodplain for a distance of about 40 air-line miles behind the dam, and all the creek bottomland on either side of the river for distances varying from a few miles up to 15 miles (in the case of Richland Creek) from the river channel. From recent aerial photographs I estimate that approximately 20 - 30% of this area is presently in woodlands, principally bottomland hardwood forest. The largest tracts of remaining forest are located along Chambers, Richland, Tehuacana, Cedar, Indian, and Rush creeks, and along the Trinity River in the Sanders Creek and Twin Lakes area (between highways 85 and 31 northwest of Trinidad), on the Stephens Lake Ranch, and in the Creslenn Park area. At least 30,000 - 35,000 total acres of bottomland hardwood forests will probably be inundated by creation of the Tennessee Colony Reservoir.

The most serious effects of the reservoir on wildlife populations will be to forest-inhabiting species, since it is these species which are already declining or are limited in numbers by lack of suitable habitat (See Greenway, 1967). Because of the fertility of floodplains and bottomlands, these areas have been largely cleared for agricultural purposes over much of the southeastern United States, and bottomland hardwood forests, including those along the Trinity River, are continuing to decline at an alarming rate. As the forests disappear so do the floral and faunal elements associated with them. In the Tennessee Colony area there are not very many hardwood forests left, and those that exist are not of high "quality", yet their destruction will bring about a still further decline in many species of birds and mammals.

I have predicted population changes in avian and mammalian faunas in Tables D-4 and D-5. In general, species which will decline are those closely associated with bottomland hardwood forests, and species which will increase in number are those of aquatic habitats, principally waterfow, large wading birds, and various small shorebirds. Only one species of mammal, the nutria, is likely to undergo a significant population increase. Wildlife associated with pastures, open fields, thickets, woodland edges, and dry upland forests will probably experience little overall population change in the Tennessee Colony Area, although there will be some loss of habitat even to these species.

The fertile, well-watered soils of bottomland hardwood forests produce more and better food for deer than do upland sites (Stranksy and Halls, 1962; Collins, 1961; Lay, 1965; Segelquist and Green, 1968). Therefore, it can be predicted that deer populations will decline in the Tennessee Colony area following creation of the reservoir, and there will be a loss in revenue from sportsmen who will have to go elsewhere for their deer. Another popular game animal, the gray squirrel is confined to bottomland hardwoods (Goodrum, 1964), and can be expected to decline as forests become flooded.

On the positive side of the ledger, sportsmen will probably have more waterfowl to shoot if the proposed reservoir is created. It should be pointed out, however, that the mere presence of open water does not guarantee large waterfowl populations. There need to be shallow areas with abundant aquatic plants for food, and a good fish population for diving ducks. Adequate precautions need to be taken to prevent botulism, and there is danger from siltation, aquatic weeds (such as Myriophyllum), pesticide pollution, and oil pollution (both from oil field brines and barge traffic if the reservoir is used as a major waterway). These points cannot be emphasized too strongly, and if precautionary measures are not taken the reservoir could become unfit for wildlife, as well as for humans. Furthermore, many recreational uses such as water-skiing, boating, campgrounds, swimming, and public parks, conflict with the interests of fishermen and hunters, and it will be necessary to set aside areas wherein wildlife can be protected from such activities. It should also be stressed that the reservoir will inundate many acres of already existing waterfowl habitat, and Mr. Walt Daniel, a resident game biologist in Fairfield, believes that more will be lost than will be gained in regard to waterfowl populations. Finally, it can be predicted that constant barge traffic along the length of the reservoir will result in a continual source of disturbance to wildlife populations, and if the reservoir is used as a major waterway its value for waterfowl and other fauna will be considerably reduced.

The reservoir will affect not only the immediate area around it and the land it covers, but by controlling flood waters in the river below the dam it will eliminate, at least in part, the periodic flooding which for years has built up the fertility of the floodplain, and has created sloughs and marshes valuable to wildlife. Unless provision is made to periodically divert the river through old flood channels and oxbows, these habitats will cease to be productive for animal populations. Without seasonal inundation many of the bottomland hardwood forests below the reservoir will probably disappear, and with them their wildlife.

Although it might be supposed that a large reservoir would favor the beaver population in the Tennessee Colony area, I consider it likely that beavers will decline in numbers with the flooding of the river floodplain and adjacent creeks. Beavers feed principally on the bark of trees, with willows, elm, and sweetgums being among their favorites in east Texas. Their staple food items grow along the banks of rivers and streams, and the shores of ponds which beavers themselves create. With the flooding of these low-lying areas, beavers will be pushed back to the upper arms of the reservoir, along the creeks. My observations on Cedar Creek Reservoir indicate that beavers are not as common in this area as formerly. The nutria, however, another large semi-aquatic rodent, has adapted well to this artificial environment. Unlike the beaver, the nutria feeds predominantly on herbaceous vegetation, which it finds in abundance in the quiet waters of marshes (see Evans, 1970; Atwood, 1950). Although both of these mammals often occur together, the nutria appears to be more common in marshes and ponds, whereas the beaver is apparently the more abundant of the two in the swifter-moving waters of creeks and rivers. These differences in habitat preference probably reflect the dissimilarities in their food habits.

A reservoir at site 2A will not flood any large nesting colony of herons and egrets. However, the northeast end of the proposed dam is only just over one mile away from the heronry at Sand Lake, and there is some danger that construction work on the dam might cause birds to abandon this important nesting location.

When viewed in overall perspective of the total east Texas region, the swamps, marshes, sloughs, and woodlands to be lost in this project do not seem very great. No endemic or unique birds or mammals are present, and there is no threat to rare or endangered species. The land has already been extensively modified by man. It should be pointed out, however, that if a balanced natural ecosystem is to be maintained, it is essential to make every possible effort to preserve the relatively few remaining hardwood forests, and their associated faunas, in the Tennessee Colony area. Animal populations must be evaluated in terms not only of their economic importance, but also in terms of their ecological and scientific significance, and of their aesthetic qualities.

Table D-4 Summary of bird distribution and abundance along the Trinity River in Anderson, Freestone, Henderson, and Navarro counties, with predicted short-term population changes following creation of the proposed Tennessee Colony dam and reservoir.

Species[a]	Rel Abundance[b] by Season				Habitat Preference[c]	Pred. Pop. Change[d]
	Spring	Summer	Autumn	Winter		
common loon	R		R	R	W	+
horned grebe	R		R	R	W	+
eared grebe	U		U	U	W	+
pied-billed grebe*	C	U	C	C	W, M	+
white pelican	U		C		W	+
double-crested cormorant	C	R	A	U	W, M	+

Table D-4 continued

anhinga*..............................	U	U	U		W,M	+
great blue heron*......................	C	C	C	U	Sh, M	+
green heron*...........................	C	C	U		Sh, M	0
little blue heron*.....................	C	C	U		Sh, M	+
cattle egret*..........................	A	A	C	R	O, M	+
common egret*..........................	A	A	A	R	Sh, M	+
snowy egret*...........................	U	U	U		Sh, M	+
Louisiana heron........................			U		Sh, M	+
black-crowned night heron*.............	U	U	U	R	Sh, M	+
yellow-crowned night heron*............	U	U	U		M	-
least bittern*.........................	R	R	R		M	0
American bittern.......................	U		U	R	M	0
wood ibis..............................		U	U		Sh, M	+
white ibis.............................		R	R		Sh, M	+
roseate spoonbill......................		R	R		Sh, M	+
Canada goose...........................	C		C	U	W, O	+

Table D-4 Continued

white-fronted goose	R		R		W, O	+
snow goose	A		A	C	W, O	+
blue goose	A		A	C	W, O	+
mallard*	C	R	C	C	W, M	+
gadwall	A		A	C	W, M	+
pintail	A		A	C	W, M	+
green-winged teal	A		A	C	W, M	+
blue-winged teal*	A	R	A		W, M	+
cinnamon teal	R		R		W, M	+
American widgeon	A		A	C	W, M	+
shoveler	C		C	U	W, M	+
wood duck*	C	U	C	C	W, M	0
redhead	U		U	U	W	+
ring-necked duck	A		A	C	W	+
canvasback	U		U	U	W	+
lesser scaup	A		A	C	W	+
common goldeneye	R		R	R	W	+

Table D-4 Continued

bufflehead	U		U	R	W	+
ruddy duck	C		C	U	W	+
hooded merganser	U		U	U	W	+
common merganser	R		R	R	W	+
red-breasted merganser	R		R		W	+
turkey vulture*	A	A	A	A	O, Wd	0
black vulture*	C	C	C	C	O, Wd	0
Mississippi kite	U		U		O	0
sharp-shinned hawk	U		U	R	Wd, F	-
Cooper's hawk	U	R	U	R	Wd, F	-
red-tailed hawk*	U	U	U	C	O, Wd	0
Harlan's hawk				R	O, Wd	0
red-shouldered hawk*	C	C	C	C	Wd, F	-
broad-winged hawk*	C	U	C		O, Wd	0
rough-legged hawk				R	O	0
bald eagle	R		R	R	Sh, W	+
marsh hawk	U		U	U	O, M	0

Table D-4 Continued

osprey	R		R		Sh, W	+
peregrine falcon	R		R		Sh, O	0
merlin	R		R		Sh, O	0
kestrel*	C	U	C	C	O	0
bobwhite*	C	C	C	C	Th, Wd	-
turkey*	R	R	R	R	Wd, Th	-
sandhill crane	R		R		O	0
king rail	R	R	R	R	M	0
sora	U		U	R	M	0
purple gallinule*		R			M	-
common gallinule*		R			M	0
American coot	A	R	A	C	M, W	+
sermipalmated plover	U		U		Sh	+
killdeer*	C	C	C	A	O, Sh	0
American golden plover	U		R		O	0
black-bellied plover	U		U		Sh	+
American woodcock			U	U	F, M	-

Table D-4 Continued

common snipe	C	C	U	Sh, M	0
whimbrel	R			Sh, O	+
upland plover	U	U		O	0
spotted sandpiper	C	C	R	Sh	+
solitary sandpiper	U	U		Sh, M	0
willet	R	R		Sh	+
greater yellowlegs	C	C		Sh	+
lesser yellowlegs	C	C		Sh	+
pectoral sandpiper	C	C		O,Sh	+
white-rumped sandpiper	R	R		Sh	+
Baird's sandpiper	R	R		Sh	+
least sandpiper	C	C	R	Sh	+
dunlin	R	R		Sh	+
Short-billed dowitcher	R	R		Sh	+
long-billed dowitcher	U	U		Sh	+
stilt sandpiper	U	U		Sh	+
semipalmated sandpiper	C	C		Sh	+
western sandpiper	U	U		Sh	+

Table D-4 Continued

buff-breasted sandpiper	R		R		O	0
marbled godwit	R				Sh	+
sanderling	R		R		Sh	+
American avocet	R		R		Sh	+
Wilson's phalarope	U		R		Sh	+
herring gull	U		U	R	W	+
ring-billed gull	C		C	U	W	+
Franklin's gull	C		A		W	+
Bonaparte's gull	U		U	R	W	+
Forster's tern	U		C		W	+
common tern	R		R		W	+
Caspian tern			R		W	+
black tern	U		U		W	+
mourning dove*	A	A	A	A	O, Th	0
yellow-billed cuckoo*	C	C	U		Wd, F	-
black-billed cuckoo	R		R		Wd, F	-
roadrunner*	U	U	U	U	Wd, Th	0

Table D-4 Continued

barn owl*	R	R	R	R	Wd, O	0
screech owl*	C	C	C	C	Wd, F	-
great horned owl*	U	U	U	U	Wd, F	-
barred owl*	C	C	C	C	F, Wd	-
long-eared owl				R	Wd	0
short-eared owl				R	O, M	0
chuck-will's-widow*	U	C			F, Wd	-
whip-poor-will	R		R		F, Wd	-
common nighthawk*	U	U			O	0
chimney swift*	A	A	C		O	0
ruby-throated hummingbird*	C	U	U		Wd, T	0
belted kingfisher*	C	C	C	C	Sh, W	0
yellow-shafted flicker*	C	U	C	C	Wd, T	-
pileated woodpecker*	U	U	U	U	F, Wd	-
red-bellied woodpecker*	C	C	C	C	F, Wd	-
red-headed woodpecker*	C	C	C	C	Wd, T	0
yellow-bellied sapsucker	C		C	C	F, Wd	-
hairy woodpecker*	U	U	U	U	F, Wd	-

Table D-4 Continued

downy woodpecker*	C	C	C	C	F, Wd	-
eastern kingbird*	C	C	U		O, T	0
scissor-tailed flycatcher*	C	C	A		O	0
great crested flycatcher*	C	U	U		F, Wd	-
eastern phoebe*	C	R	C	C	Wd, Sh	0
yellow-bellied flycatcher	R		R		Wd, F	-
Acadian flycatcher*	U	U	R		F, Wd	-
Traill's flycatcher	R				Th, M	0
least flycatcher	U		R		Wd, Th	0
eastern wood pewee*	C	C	C		Wd, F	-
olive-sided flycatcher	R		R		Wd, F	-
horned lark	R		R	R	O	0
tree swallow	R		R		W, Wd	+
bank swallow	U	R	U		O, W	0
rough-winged swallow*	C	U	C		O, W	0
barn swallow*	A	U	A		O, W	0
cliff swallow	R	R	R		O, W	0
purple martin*	A	A	C		O, W	0

Table D-4 Continued

blue jay*..............................	C	C	C	C	F, Wd, T	-
common crow*...........................	A	A	A	A	F, Wd, O	-
Carolina chickadee*....................	C	C	C	C	F, Wd	-
tufted titmouse*.......................	C	C	C	C	F, Wd	-
white-breasted nuthatch*...............	U	U	U	U	F, Wd	-
red-breasted nuthatch..................				R	Wd	0
brown creeper..........................	U		U	U	F, Wd	-
house wren.............................	U		C	R	Th	0
winter wren............................	R		R	R	F, Th	-
Bewick's wren..........................	U		U	U	Th, Wd	0
Carolina wren*.........................	C	C	C	C	F, Th	-
long-billed marsh wren.................	R		R	R	M	0
short-billed marsh wren................	U		R		M	0
mockingbird*...........................	C	C	C	C	Th, T	0
catbird*...............................	U	R	R		Th, T	0
brown thrasher*........................	C	U	C	C	Th, T	0
robin*.................................	C	U	C	A	T, O	0
wood thrush*...........................	U	U	R		F, Wd	-

Table D-4 Continued

hermit thrush.........................	C		U	U	F, Wd	-
Swainson's thrush.....................	U		R		F, Wd	-
gray-cheeked thrush...................	U		R		F, Wd	-
veery.................................	R		R		F, Wd	-
eastern bluebird*.....................	C	C	C	A	T, O	0
blue-gray gnatcatcher*................	C	U	U		F, Wd	-
golden-crowned kinglet................	C		C	C	F, Wd	-
ruby-crowned kinglet..................	C		C	C	F, Wd	-
water pipit...........................	U		C	U	O, Sh	0
Spragues's pipit......................	R		R	R	O	0
cedar waxwing.........................	A		C	A	T, F	0
loggerhead shrike*....................	C	U	C	C	O	0
starling*.............................	A	A	A	A	T, O	0
white-eyed vireo*.....................	C	C	U		Th	0
Bell's vireo..........................	R	R			Th	0
yellow-throated vireo.................	U	U	U		F, Wd	-
solitary vireo........................	U		U		F, Wd	-
red-eyed vireo*.......................	C	C	U		F, Wd	-

Table D-4 Continued

Philadelphio vireo........................	U		R		F, Wd	-
warbling vireo........................	U	R	R		F, Sh	-
black & white warbler*...................	C	U	R		F, Wd	-
prothonotary warbler*....................	U	U	R		F, Sh	-
Swainson's warbler.......................	R				F	-
worm-eating warbler,.....................	R				F, Wd	-
golden--winged warbler...................	R				Th, F	-
blue-winged warbler......................	R	R			Th, F	-
Tennessee warbler........................	C		R		F, Wd	-
orange--crowned warbler..................	U		U	R	F, Th	-
Nashville warbler........................	C		U		F, Wd	-
parula warbler*..........................	C	C	U		F	-
yellow warbler...........................	U		R		Th, M	0
magnolia warbler.........................	C		R		F, Wd	-
myrtle warbler...........................	U		U	C	F, Wd	-
black-throated green warbler	U		R		F, Wd	-
cerulean warbler.........................	R				F, Wd	-
blackburnian warbler.....................	U		R		F, Wd	-

Table D-4 Continued

yellow-throated warbler*................	U	R			F, Wd	-
chestnut-sided warbler..................	C		R		F, Th	-
bay-breasted warbler....................	U		R		F, Wd	-
pine warbler*...........................	R	R	R	R	Wd	0
prairie warbler.........................	R				Th	0
ovenbird................................	R		R		Wd, F	-
northern waterthrush....................	U		R		Sh, F	-
Louisiana waterthrush*..................	R	R	R		Sh, F	-
Kentucky warbler*.......................	U	U			F, Wd	-
Connecticut warbler.....................	R				F, Th	-
mourning warbler........................	R		R		F, Th	-
yellowthroat*...........................	C	C	U	R	M, Th	0
yellow-breasted chat*...................	C	C	U		Th	0
hooded warbler*.........................	R	R			F	-
Wilson's warbler,.......................	U		U		F, Th	-
Canada warbler..........................	U		R		F	-
American redstart.......................	U		R		F, Wd	-
house sparrow*..........................	A	A	A	A	T, O	0

Table D-4 Continued

eastern meadowlark........................	A	A	A	A	O	0
western meadowlark........................				R	O	0
yellow-headed blackbird..................	R		R		M, O	+
redwinged blackbird*.....................	A	A	A	A	M, O	0
orchard oriole*..........................	C	C	R		Th, Th	0
Baltimore oriole*........................	U	R	R		T	0
rusty blackbird..........................	U			C	F, T, O	-
Brewer's blackbird.......................				A	O	0
common grackle*..........................	A	U	C	A	T, Th	0
brown-headed cowbird*....................	A	A	A	A	O, T	0
scarlet tanager..........................	R				F, Wd	-
summer tanager*..........................	C	C	U		Wd, F	-
cardinal*................................	A	A	A	A	Wd, Th	-
rose-breasted grosbeak...................	U		R		F, T	-
blue grosbeak*...........................	C	C	U		Th	0
indigo bunting*..........................	C	C	C		Th	0
painted bunting*.........................	C	C	U		Th	0
dickcissel*..............................	C	C	U		O	0

Table D-4 Continued

purple finch...........................	C			C	F, Wd	-
pine siskin............................	C			C	Wd, Th	0
American goldfinch.....................	A		C	A	Wd, Th	0
rufous-sided towhee....................	U		U	U	F, Wd, Th	-
savannah sparrow.......................	C		C	C	O, Th	0
grasshopper sparrow*...................	U	R	R		O	0
LeConte's sparrow......................	U		U	U	Th, O	0
vesper sparrow.........................	C		U	C	Th, O	0
lark sparrow*..........................	C	C	U	C	O, Th	0
slate-colored junco....................	C		C	A	Th, Wd	0
Oregon junco...........................				R	Th, Wd	0
chipping sparrow*......................	U	R	U	R	Wd, Th	0
clay-colored sparrow...................	R				Th, T	0
field sparrow*.........................	C	C	C	C	Th	0
Harris' sparrow........................	U			C	Th	0
white-crowned sparrow..................	U		U	C	Th	0
white-throated sparrow.................	C		C	A	F, Wd, Th	-

Table D-4 Continued

fox sparrow..........................	U	U	U	F, Th	-
Lincoln's sparrow....................	C	C	U	Th	0
swamp sparrow........................	U	U	U	M, Th	0
song sparrow.........................	U	U	C	Th, M	0
lapland longspur.....................			R	O	0
chestnut-collared longspur............			R	O	0

a - breeding species are denoted by an asterisk

b - A: abundant (more than 100 individuals in a day);

C: common (11-100 individuals in a day);

U: uncommon (1-10 individuals in a day);

R: rare (1-20 individuals in a season).

c - F: bottomland hardwood forest;

M: marshes and swamps;

O: fields, pastures, croplands, and other open country;

Sh: lake and stream shores and mudflats;

T: towns, parks, and scattered trees;

Th: thickets and weedy woodland edges;

Table D-4 Continued

W: open water of lakes, ponds, and rivers;

Wd: dry pine and deciduous woodlands.

d - +: population increase;

-: population decrease;

0: little or no population change

Table D-5 Summary of mammal distribution and abundance along the Trinity River in Anderson, Freestone, Henderson, and Navarro counties, with predicted short term population changes following creation of the proposed Tennessee Colony dam and reservoir.

Species	Relative Abundance[a]	Habitat Preference[b]	Pred. Pop. Change[c]
Didelphis marsupialis	U	F, Wd, O	-
Scalopus aquaticus	U	Wd, O	0
Blarina brevicauda	R	F, Wd, Gr	-
Cryptotis parva	U	Gr	0
Pipistrellus subflavus	C	H, Wd, R	0
Eptesicus fuscus	U	F, H	-
Lasiurus borealis	C	O	0
Nycticeius humeralis	A	F, R	-
Tadarida cynocephala	C	H, Wd, O	0
Dasypus novemcinctus	A	F, Wd, O	-
Lepus californicus	R	Gr	0
Sylvilagus floridanus	C	Th, Gr	0

Table D-5 Continued

Sylvilagus aquaticus	C	M	0
Citellus tridecemlineatus	R	O, Gr	0
Sciurus carolinensis	C	F	-
Sciurus niger	A	Wd, F	-
Glaucomys volans	C	Wd, F	-
Geomys bursarius	A	O, Gr	0
Perognathus hispidus	U	Th, Gr	0
Castor canadensis	C	R, M	-
Reithrodontomys fulvescens	U	Th, Gr	0
Baiomys taylori	R	Gr, Th	0
Peromyscus maniculatus	R	Gr, Th	0
Peromyscus leucopus	C	F, R	-
Peromyscus gossypinus	C	F, R	-
Peromyscus nuttalli	R	F	-
Sigmodon hispidus	A	Gr,	0
Neotoma floridana	C	F	-
Mus musculus	A	H	0

Table D-5 Continued

Rattus rattus..........................	A	H	0
Rattus norvegicus......................	C	H, Th	0
Myocastor coypus.......................	C	M	+
Procyon lotor..........................	C	R, F	-
Bassariscus astutus....................	R	Rk, Th, Wd	0
Mustela frenata........................	R	Gr, O	0
Mustela vison..........................	U	R, F	-
Spilogale putorius.....................	R	Wd, Gr, O	0
Mephitis mephitis......................	U	Wd, Th, O	0
Vulpes fulva...........................	U	Wd, Th, O	0
Urocyon cinereoargenteus...............	C	F, Wd, Th	-
Canis latrans..........................	C	Gr, O, Wd	0
Lynx rufus.............................	U	Rk, Th, Wd	0
Odocoileus virginianus.................	C	F, Wd, O	-

a - A: abundant; C: common; U: uncommon; R: rare

b - F: bottomland hardwood forests

Gr: grasslands, meadows, and old fields

Table D-5 Continued

H: human habitations

M: marshes, swamps, sloughs, and ponds

O: open farmland, orchards, and scattered trees

R: rivers, streams, and lake shores

Rk: rocky areas

Th: thickets and brush piles

Wd: dry pine or deciduous woodlands

c - +: population increase

-: population decrease

0: no significant population change

CONCLUSIONS

1. Community structure of benthic macroinvertebrates of the Trinity River tributaries reflects a low diversity, probably due to an unsuitable scoured substrate.
2. Benthic fauna are typically pool or lake types, rather than typical stream organisms, because the streams lack riffle areas and are intermittent.
3. Populations of some benthic forms may be enhanced by the creation of the proposed impoundment, but poor water quality could restrict their abundance.
4. A potential fishery will exist due to an enlarged habitat and the short plankton-to-fish food web common in reservoirs. However, oxygen, toxicity, and turbidity levels are presently critical in the Trinity River at the Tennessee Colony site, and would probably restrict a healthy warm water fishery in the upper end of the proposed reservoir.
5. Ten fish species may be eliminated from the site, 15 will probalby be restricted to waters above or below the reservoir, 15 should benefit from the impoundment, and 21 additional species will probably increase in numbers if rooted vegetation along the reservoir margins becomes established.

6. Twelve amphibian species and 16 species of reptiles will be forced to emigrate from the bottomland forested areas upon filling of the Tennessee Colony Reservoir. Five herptile species will be restricted to flowing water habitats near the reservoir, while 2 amphibian and 17 reptilian species may benefit by increased marginal areas formed by the reservoir.
7. A highly diversified bird and mammal fauna presently exists in the Tennessee Colony area, although there are no endemic or unique species. Beavers occur here in higher densities than perhaps anywhere else in Texas.
8. Deer, squirrel, and waterfowl are extensively hunted, and to a lesser degree numerous other game species. Most of these populations, particularly deer, will be reduced as a result of habitat destruction.
9. There are several important nesting sites of herons and egrets, the largest of which is at Sand Lake.
10. Rare or endangered species known to occur in small numbers during the non-breeding season are the Bald Eagle, Osprey, and Peregrine Falcon. These species are not likely to decline as a result of the proposed project, and in fact their populations may be slightly favored.
11. Destruction of bottomland hardwood forests will cause

a decline in many mammals and in a large number of breeding and non-breeding species of birds. On the other hand, winter populations of waterfowl, migratory shorebirds, and certain other aquatic birds may increase. The loss of forest populations, however, will be greater and of more significance than the gain in aquatic populations, so that the net effect of the proposed reservoir on the avian and mammalian faunas will be detrimental.

12. Bird and mammal populations downstream from the proposed reservoir are likely to be adversely affected by the elimination of the periodic inundation of the floodplain, which will result in the drying up of marshes and sloughs, and perhaps eventual elimination of some of the wet-adapted forests.

13. Pesticide concentrations, oil pollution, siltation, and choking by water weeds are some of the wildlife hazards which will need to be guarded against in the new reservoir.

14. Barge traffic along the reservoir will greatly reduce the potential of the reservoir as a suitable environment for waterfowl and other wildlife.

RECOMMENDATIONS

1. Pollution abatement in the Dallas-Ft. Worth area should be concluded before impoundment of the Tennes-

see Colony site because of the adverse conditions now imposed on aquatic life.

2. Preimpoundment surveys of fishes in the Trinity River and its tributaries should be conducted to identify potential fishery management problems.
3. The Tennessee Colony Reservoir should be closely monitored for:

   (a) pesticide, chemical, sewage, and oil pollution

   (b) silting

   (c) choking by aquatic weeds
4. The Gus Engeling Wildlife Management Area and the Sand Lake area on Beaver and Catfish creeks should not be inundated.
5. The river below the dam should have provisions along its course for diverting water periodically into existing marshes, sloughs, oxbows, and swamps.
6. Bottomland hardwood forests remaining along the shores of the reservoir should be set aside for complete protection of the flora and fauna.

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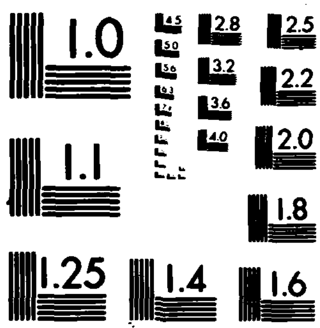

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APPENDIX E

EUTROPHICATION AND
PESTICIDE ELEMENTS

by

Jack D. McCullough

With the
assistance of:

Joe Dawson
K. C. Rudy
Donna Turner
P. M. Adler

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INTRODUCTION

The major benefits in constructing the Tennessee Colony impoundment include water supply, flood control, navigation, recreation, and wildlife conservation. Eutrophication as well as insecticide and herbicide pollution may adversely effect several of the possible beneficial results of this water resources development project. Lee (1970) states that eutrophication, defined by Ohle (1965) as "enrichment in nutrients and increases of plant production," is one of the most significant causes of water quality problems in North America. Channelization of a river by dredging the basin and constructing locks and dams will alter the lotic environment in many ways, including changes in water depth, increased detention time, and the possibility of thermal stratification. Each has an influence upon the normal biological, physical and chemical processes in the aquatic ecosystem which may have significant impact on eutrophic conditions. The expansion of insecticide use is a post World War II phenomenon. Concern mounted over insecticide pollution in 1962 when a sampling program of 101 stations revealed DDT in 32 samples from nine rivers in the United States (Breidenback and Lichtenberg, 1963). Schafer (1969) reported 40% of 500 samples of water collected from the Mississippi River contained Dieldrin. Bailey and Hannum (1965) have presented data showing a high correlation between heavy insecticide application and insecticide concentrations in river waters and sediments. The proposed Tennessee Colony impoundment will flood extensive bottom lands in Navarro, Freestone, Henderson, and Anderson counties. Because of the extensive agricultural enterprise in those counties, the question arises as to the possible environmental impact from insecticide and herbicide usage.

The primary objectives of this portion of the project will be to evaluate the present eutrophic condition of the Trinity River; to assess the present application of pesticides in the counties surrounding the proposed Tennessee Colony impoundment; and to estimate the degree of pollution by pesticides in the river waters. Having established these points, predictions will be made as to the possible impact of channelization and construction of an impoundment on the aquatic environment.

METHODS

1. Eutrophication Element:

Stewart and Rohlick (1967) suggest several parameters which may be used as indices of eutrophication. Basically, the following indices have been used and will be discussed subsequent to the discription of collecting stations:

- A. Standing crop of phytoplankton
- B. Standing crop of attached algae
- C. Amount of chlorophyll in water samples
- D. Transparency of the water
- E. Estimates of primary productivity
- F. Oxygen concentrations
- G. Phosphorus and nitrogen content

Three collecting stations were established on the Trinity River in the proposed Tennessee Colony reservoir area and were assumed to be representative of eutrophic conditions in that general portion of the river basin. Station I was established 500 yards upstream from proposed dam site IIA on the Coffield State Prison Farm. Station II was established 500 yards upstream from the bridge where U. S. Hwy. 287 crosses the Trinity River near Cayuga, Texas. Station II is approximately 35 river miles upstream from Station I. Station III was established 3 miles upstream from the bridge where State Hwy. 31 crosses the Trinity River near Trinidad, Texas. Station III is upstream from the NIPAC fertilizer plant near Trinidad, Texas and

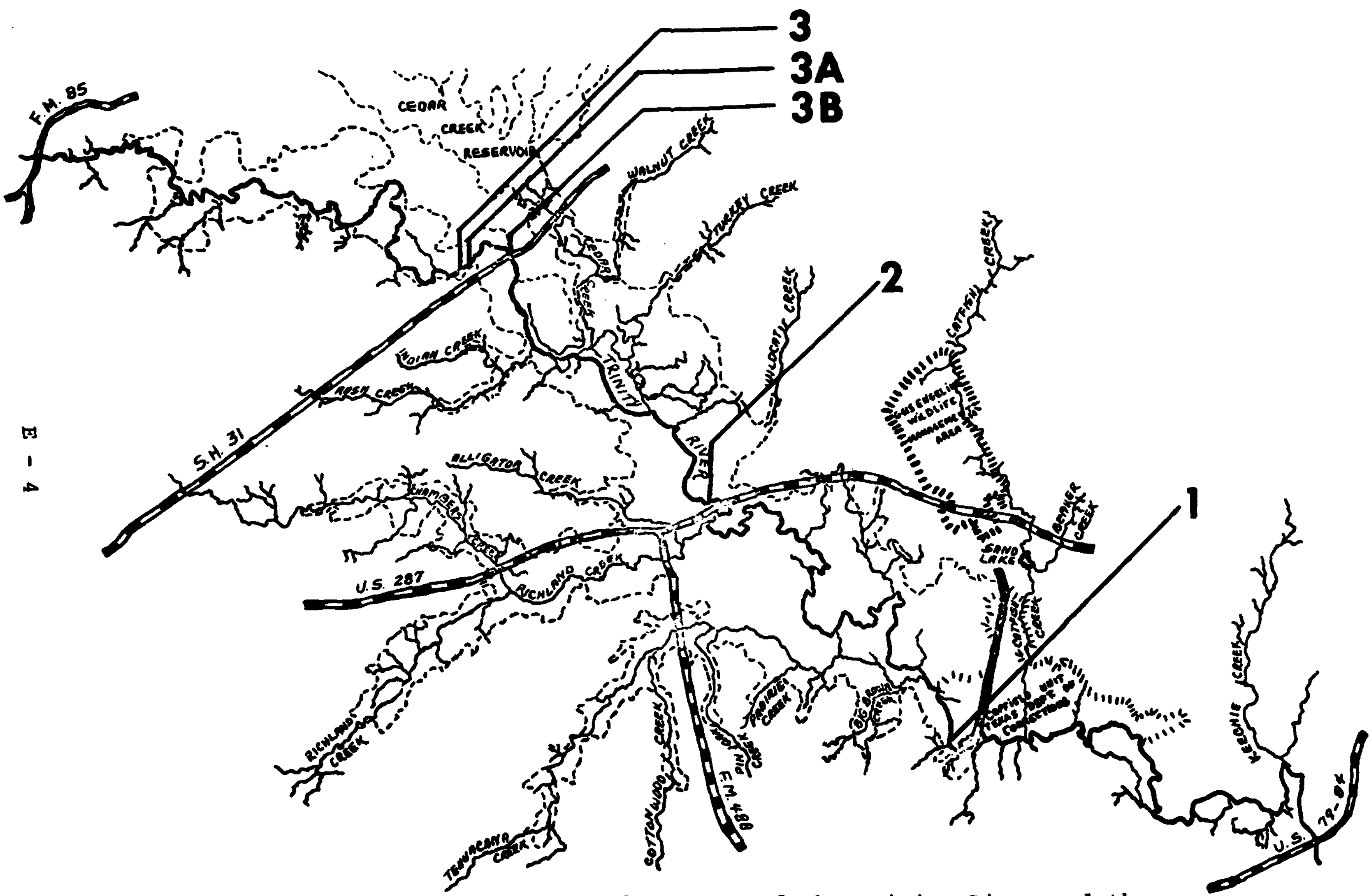


Figure E-1. Map of the Tennessee Colony area of the Trinity River and the location of sampling stations.

is approximately 25 river miles upstream from Station II.

A. Standing crop of phytoplankton:

Standing crop of phytoplankton was based on collections of surface water samples at each station from September through November, 1971. Concentration of samples for cell counts was accomplished by passing one liter of each water sample through a Foerst electrical plankton centrifuge three times (Hartmann, 1958). The volume of the concentrate was then determined and aliquots were taken for examination. Counts were determined using a phase contrast compound microscope and hemacytometer. Direct microscopic counts of phytoplankters were expanded to cells per liter by the equation given in Welch (1948). In general, organisms were identified to genus only.

B. Standing crop of attached algae:

Estimates of standing crop of attached algae were done by allowing the periphyton algae to colonize submerged artificial substrates according to techniques suggested by Sladeckova (1962) and Sladeckova and Sladecek (1963). The periphyton samplers were placed at each collecting station and consisted of a plastic float supporting a wooden slide rack constructed according to the directions given in Welch (1948). The slide rack held six 1 X 3 inch glass microscope slides. The slide racks were submerged two inches from the surface and the slides were held with the long axes parallel to, and their short axes perpendicular to, the water surface. The slides were collected at two week intervals and replaced with clean slides. The slides with attached algae were placed in vials and filled with distilled water. The periphyton was scraped from the slides and the biomass was determined by obtaining dry and ash-free weights. The algae removed from the slide was dried twenty four hours at 105°C and fired for one hour at 500°C.

C. Chlorophyll a determinations:

Chlorophyll a concentrations were determined from phytoplankton water samples collected at each sampling station. A 100 ml. aliquot of the phytoplankton sample was filtered through a millipore filter Type HA with 0.45 micron pores. The concentration of chlorophyll a was subsequently determined by the technique described by Richards and Thompson (1952) with revised equations by Parsons and Strickland (1964). Optical density values were determined using a Coleman Universal Model 14 Spectrophotometer.

D. Transparency:

Transparency of the water was determined by the Secchi Disc method described in Welch (1948).

E. Primary Productivity:

Estimates of primary productivity were based on rates of biomass increase of periphyton using the technique outlined by Sladecek and Sladeckova (1964). Periphyton samplers, previously described were used to collect algae. Glass slides were allowed to colonize for two week periods.

Biomass accumulation was determined as previously described and was expressed as mg. dry wt./m^2 of substrate/day and as mg. ash-free dry wt./m^2 of substrate/day.

F. Oxygen Concentrations:

Surface oxygen determinations were made at each collecting station at monthly intervals. Determinations were done using a Yellow Springs Oxygen Analyzer Model 54.

G. Phosphorus and nitrogen determinations:

Water samples for chemical analysis were collected at the surface from each station at monthly intervals. Orthophosphates, nitrate nitrogen, nitrite nitrogen, and ammonia nitrogen were determined colorimetrically. Orthophophates were determined by the amino-napthol-sulfonic acid method, nitrate nitrogen was determined by the cadmium reduction method, nitrite nitrogen was determined by the dizaotization method and ammonia nitrogen by the Nessler method.

Other chemical and biological parameters:

Monthly estimates of the number of total coliform bacteria at each collection station were made using the multiple tube fermentation technique described by Standard Methods (1971). Five day biochemical oxygen demand determinations were made monthly on water samples collected at each collecting station using the procedures outlined by Standard Methods (1971). Sulfates were determined by the barium sulfate turbidimetric method and conductivity by a Lab-Line Lectro Mho-meter. The pH of the water samples was determined in the lab with a Coleman Metrion IV pH meter and surface water temperature was determined with a Yellow Springs Recorder Model 54 with a temperature probe.

2. Diversity Index Analysis:

A mathematical expression of the ratio between numbers of species and individuals in a biotic community is referred to as a diversity index (Odum, 1959). The equation $\bar{d} = (1/n)(\log_2 n! - \sum_{1}^{s} \log_2 n_i!)$ reported by Brillouin (1962) as a measure of diversity (or information) per individual was used where n is the number of individuals in s species, and n_i is the number of individuals in the i'^{th} species with logarithms interpreted to base 2. Warren (1971) reports that reductions in community diversity can be used as an index of environmental change such as the introduction of domestic or industrial effluents into an aquatic ecosystem. In this study, diversity index values were used as an index of pollution. The community diversity of the periphyton diatoms was used, based on samples collected at the three stations previously mentioned. Two additional stations were employed at Station III. Station III-A was located three hundred yards below the outfall from the NIPAC plant near Trinidad, Texas, and Station III-B was located three river miles downstream from the NIPAC plant outfall. Periphyton samplers were constructed as previously described. Slides were allowed to become colonized by algae for two weeks and were then collected in vials filled with distilled water. Weber and Raschke (1970) report that a two week exposure period is sufficiently long to permit development of abundant periphyton, yet is short enough to reflect short-term changes in water quality. The periphyton was scraped from the slides, diatom frustules cleaned and mounted in hyrax on slides for microscopic examination. Frustules were examined under oil immersion, 1000 magnification, with a phase contrast microscope. Each sample was evaluated by identifying 100 diatoms to species on each slide. Individuals were selected by a transect method. These data were then used to calculate the diversity indices utilizing a Model 40 IBM 360 computer.

3. Pesticide Element:

To assess the possible impact of agricultural usage of insecticides and herbicides on the proposed impoundment in the Tennessee Colony area, two approaches were used. First, consideration was given to the amounts of insecticides and herbicides used in the four counties bordering the impoundment: Henderson, Freestone, Anderson, and Navarro counties. Second, records of insecticide and herbicide concentrations in the Trinity River were obtained from the U. S. Geological Survey. Records of herbicide usage in the four county area were obtained from the Texas Department of Agriculture; however, there are no known sources of information on insecticide usage for these counties which are obtained by an appropriate survey. In order to make estimates of insecticide usage in the specified areas, county extension agents have estimated the acreages treated by various crop categories. These estimates have involved only agricultural uses of insecticides and do not account for the industrial, municipal, or home owner use. Estimates of specific insecticide usage were then made by utilizing the application guidelines set forth by the Agricultural Extension Service of Texas A&M University for each crop category. It should be emphasized that these data are estimates and were not obtained through actual grower contacts.

U. S. Geological Survey records for insecticide and herbicide concentrations in the waters of the Trinity River in the proposed Tennessee Colony impoundment area were not available, however, records were obtained from a collecting station on the Trinity near Rosser, Texas just above the Tennessee Colony site and at another collecting station at Romayor, Texas which is approximately 250 river miles below the Tennessee Colony site.

RESULTS AND DISCUSSION

1. Eutrophication Element:

Extreme eutrophic conditions seem to be indicated by the physiochemical data in Table E1 . Since eutrophication has been defined as an increase in nutrients and the increase in plant production, concentrations of nutrients necessary for aquatic plant growth is a good index of eutrophic conditions. The plant nutrients which are often considered to be the most significant for aquatic plant growth are orthophosphates, nitrites, nitrates and ammonia. Sawyer (1945) and Vollenweider (1968) have reported that when inorganic nitrogen from ammonia and nitrates is equal or exceeds 0.3 ppm and the orthophosphate concentration is equal or exceeded .01 ppm, one may expect nuisance plant blooms of algae and macrophytes. Mackenthun (1968) concluded that excessive growths of plants may be expected if total phosphorus exceeds 0.1 ppm in streams. Critical levels for nitrogen have been placed at 0.3 ppm of nitrate nitrogen or 0.6 ppm total nitrogen by Muller (1953) and 0.2 ppm nitrate-nitrogen by Sylvester (1961). Lee (1970) reports that Sawyer's and Vollenweider's suggested critical levels for phosphorus and nitrogen are the best estimates available. Nitrogen and orthophosphate determinations at each station exceeded these limiting values during this study. Sewage plant effluents from the Dallas-Fort Worth area and indus-

Table E-1

WATER CHEMISTRY DATA from TRINITY RIVER - TENNESSEE COLONY AREA

Date: September 18, 1971
results in parts per million except as indicated

Station	1	2	3	*	3A
Temperature C°	28.5	28	29	34	29
Dissolved Oxygen	2.3	4.8	6.2	7.8	5.2
Secchi Disc Transparency	30 cm	27 cm	20 cm	----	22 cm
Conductivity (micromhos 25°C)	835	850	855	1800	855
Sulfate	95	100	90	280	95
Orthophosphate	4.5	7.1	6.3	.8	5.5
Nitrate Nitrogen	1.5	0	0	11.1	2.3
Nitrite Nitrogen	.29	.30	.28	.31	.30
Ammonia Nitrogen	7.5	11.0	10.5	31.0	11.5
pH	7.8	7.7	7.5	5.2	7.6
B.O.D.	3.2	8.8	22.4	8.0	8.4

* Effluent from NIPAC

Table E-1. continued

WATER CHEMISTRY DATA from TRINITY RIVER - TENNESSEE COLONY AREA

Date: October 16, 1971
results in parts per million except as indicated

Station	1	2	3	*	3A
Temperature C°	22.5	23.0	23.0	27.0	23.0
Dissolved Oxygen	4.6	4.6	4.8	7.4	5.0
Secchi Disc Transparency	45 cm	45 cm	45 cm	----	35 cm
Conductivity (micromhos 25°C)	670	690	720	2250	740
Sulfate	70	80	80	325	80
Orthophosphate	2.8	2.3	2.2	2.5	1.9
Nitrate Nitrogen	6.1	4.5	3.2	9.0	5.1
Nitrite Nitrogen	.30	.29	.27	.05	.29
Ammonia Nitrogen	3.4	5.0	6.0	15.0	4.4
pH	7.6	7.8	7.7	3.0	7.7
B.O.D.	8.0	13.6	19.2	7	14.2

* Effluent from NIPAC

Table E-1. Continued

WATER CHEMISTRY DATA from TRINITY RIVER - TENNESSEE COLONY AREA

Date: November 27, 1971
results in parts per million except as indicated

Station	1	2	3	*	**	3A
Temperature C^{O}	11.9	12.5	12.0	19.0	19.0	12.0
Dissolved Oxygen	7.3	7.5	7.3	9.8	7.2	7.3
Secchi Disc Transparency	5 cm	5 cm	5 cm	----	----	5 cm
Conductivity (micromhos 25^{O}C)	440	440	420	3,150	13,000	450
Sulfate	75	55	60	450	11	65
Orthophosphate	3.1	2.9	2.7	1.5	15.5	2.8
Nitrate Nitrogen	1.5	1.5	0	16	-	1.5
Nitrite Nitrogen	.250	.185	.185	.05	-	.200
Ammonia Nitrogen	1.8	1.8	1.5	160	5,400	1.9
pH	7.3	7.3	7.2	2.8	8.9	7.3
B.O.D.	12	3.6	7.0	3.0	13.2	3.0

* Effluent from NIPAC
** Second effluent from NIPAC

trial effluents such as the NIPAC fertilizer plant at Trinidad, Texas are probably the most important contributors to the eutrophic conditions of the river. The run off of water from the extensive agricultural enterprise near the upper region of the Trinity River could also be significant. Sawyer (1947) reports that agricultural land in Wisconsin may lose by leeching up to 12 lbs. of nitrate-nitrogen and 0.6 lb. of phosphate phosphorus per square mile per day. Weibel (1964) reports that urban run off may also contribute very high amounts of nitrogen and phosphorus to streams.

The dissolved oxygen determinations and biochemical oxygen demand also suggest high organic enrichment in the water. According to the Texas Water Quality Board records, on June 2, 1971 a fish kill was reported in the Trinity River caused by extreme oxygen depletion purportedly caused by excessive organic pollution. The river frequently experiences "black water rises" which appear to be flood waters picking up organic material recently deposited in low flow and carrying it downstream. The dissolved oxygen is generally depleted temporarily during these conditions.

Transparency is probably not a very useful index of eutrophication in the Trinity River since silt as well as phytoplankton contributes to the reduction of the transparency of the water. Upstream from the Tennessee Colony site there are few trees on the Blackland Prairie where the black soil supports a dominant vegetation of grasses and causes the streams to remain muddy for long periods following rains.

The enrichment of the Trinity River in the Tennessee Colony area is further indicated by the high standing crop of phytoplankton. Figure E2 represents the cells per liter of phytoplankton collected at each station from September to November 1971. The area of each circle represents the cells per liter and the sectors in each circle represent percent composition of divisions of algae in each sample. Generally, one million phytoplankton cells per liter is considered a "bloom" condition, so that with the exception of two stations on November 4, 1971, "bloom" conditions existed at all stations and at every collecting period. Cell counts ranged from 121 X 10^5 cells per liter at Station I in October, 1971, to 4.3 X 10^5 cells per liter at Station I in November. The reduction in cell counts in November was probably due to flood conditions diluting the populations. The discharge rate was 3,897 CFS on November 4, 1971 compared with lower flow rates of less than 875 CFS on all other collection days (Table E3). Williams (1964) reports that stream flow is a very significant factor in controlling phytoplankton populations and that phytoplankton studies are more meaningful when collections are made during low flow avoiding the destructive influence of high velocity. The effect of higher flow rate was also compounded by increased silt load, and reduced light penetration which would, in turn, reduce the depth at which effective photo-

Figure E-2 . Cell counts for phytoplankton collected at stations in the Tennessee Colony area of the Trinity River.

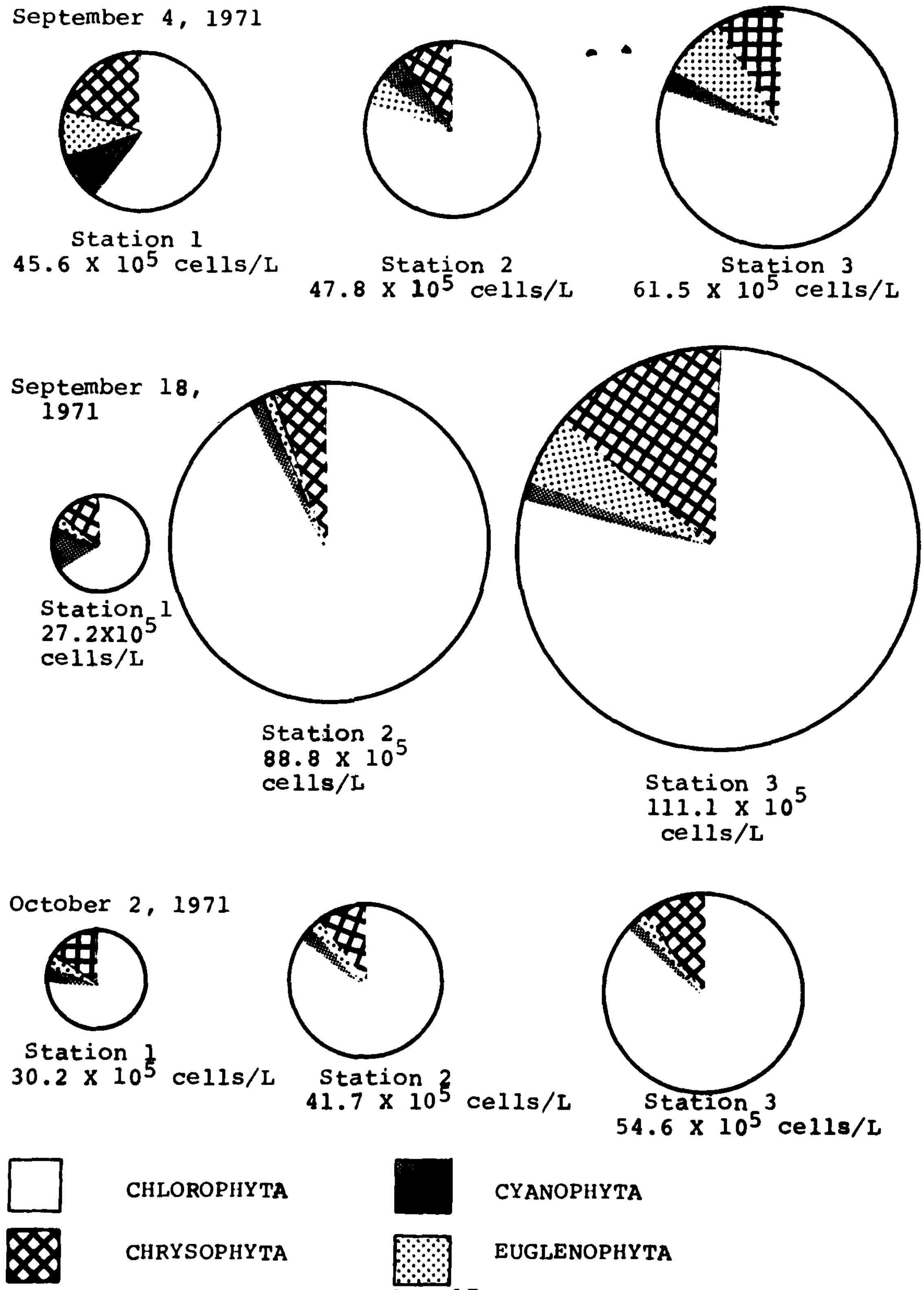
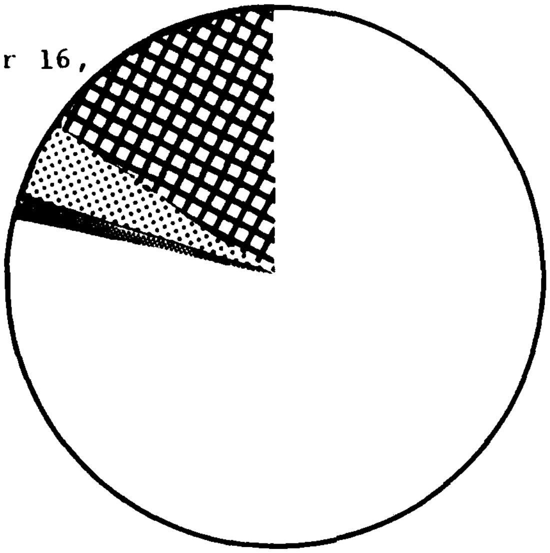
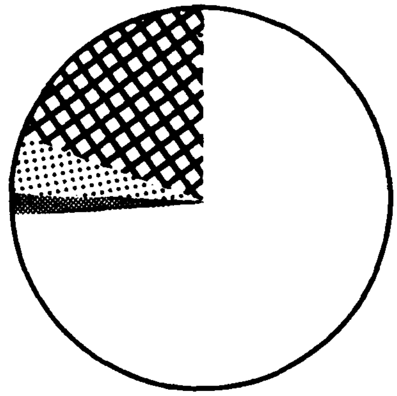


Figure E-2 Continued

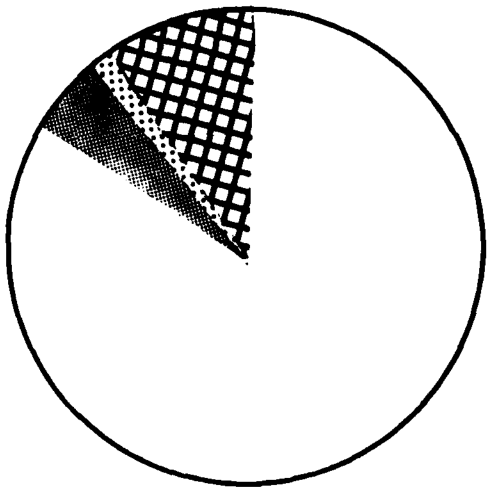
October 16, 1971



Station 1
121.2×10^5
cells/L



Station 2
85.0×10^5
cells/L



Station 3
108.8×10^5
cells/L

November 4, 1971

Station 1
4.3×10^5 cells/L

Station 2
6.8×10^5 cells/L

Station 3
11.8×10^5 cells/L

synthesis could occur. Although the river was very turbid at each collecting period with a Secchi Disc transparency of 20 to 40 centimeters, the Secchi Disc transparency was reduced to 5 centimeters during high flow on November 4, 1971. The cell counts reflected a general decrease in phytoplankton at the downstream stations. This may have been influenced by nutrients or perhaps because of inflow from Tehuacana and Richland creeks.

The relationship between chlorophyll a and phytoplankton cell counts may be found in Figure E3. There was not a strong correlation between the two variables ($r = .49$). However, Woods (1965) and Strickland (1966) report frequent inconsistencies between phytoplankton cell counts and chlorophyll a values.

The phytoplankton community was dominated by organisms which are ordinarily associated with organic enrichment and sewage (Table E5). The Trinity River samples were dominated by the genus Chlorella with genera of Chlamydomonas, Oscillatoria, Scenedesmus, Micractinium, Phacus, Euglena, and Nitzschia being common. In every sample the Division Chlorophyta was dominant. Palmer (1964) evaluated the algae listed by 110 workers as being tolerant to organic enrichment and sewage. The tolerant genera were Euglena, Oscillatoria, Chlamydomonas, Scenedesmus, Chlorella, and Nitzschia. The most tolerant were Euglena viridis, Nitzschia palea, Stigeoclonium tenne, and Oscillatoria tenuis. Generally Chlorella,

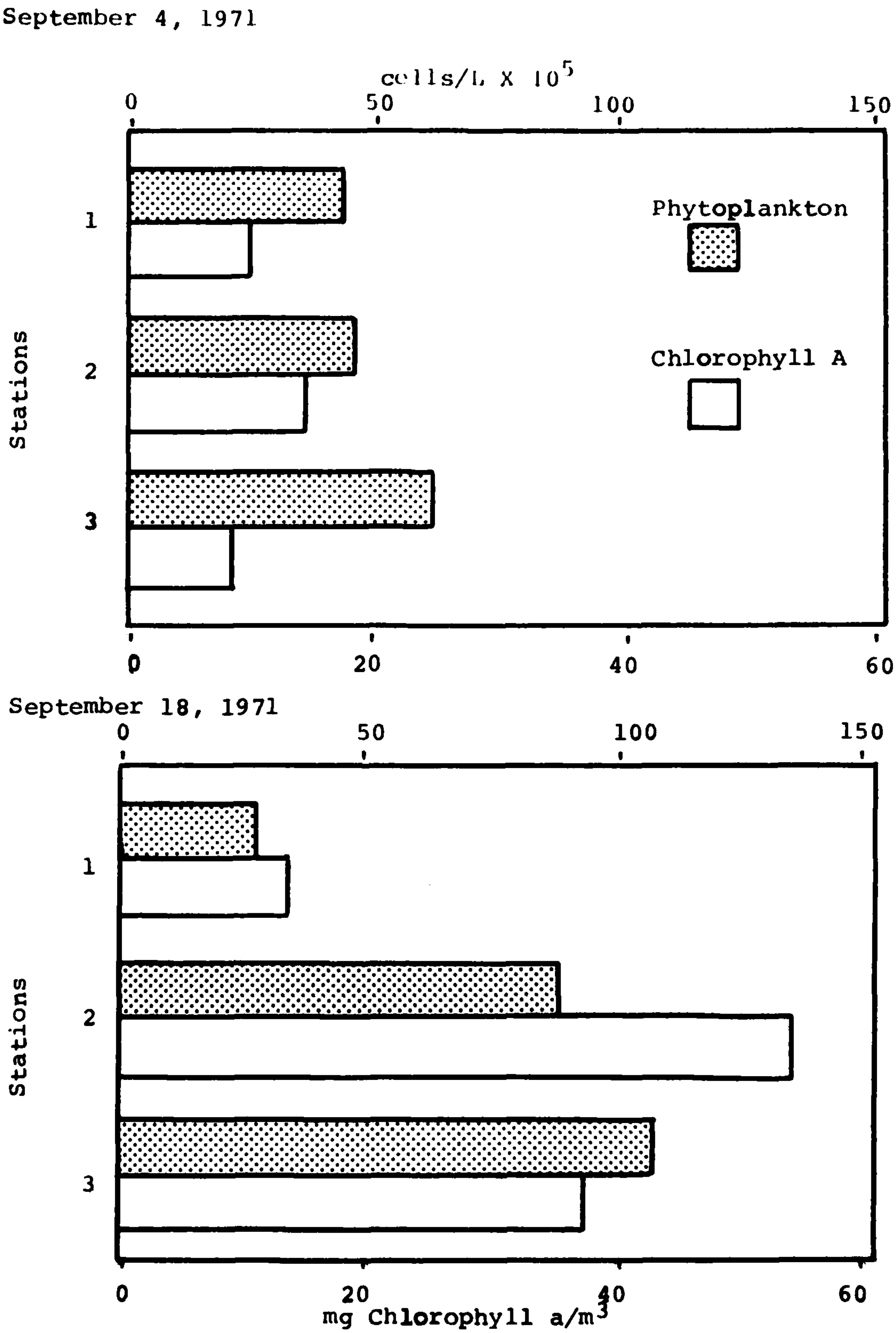
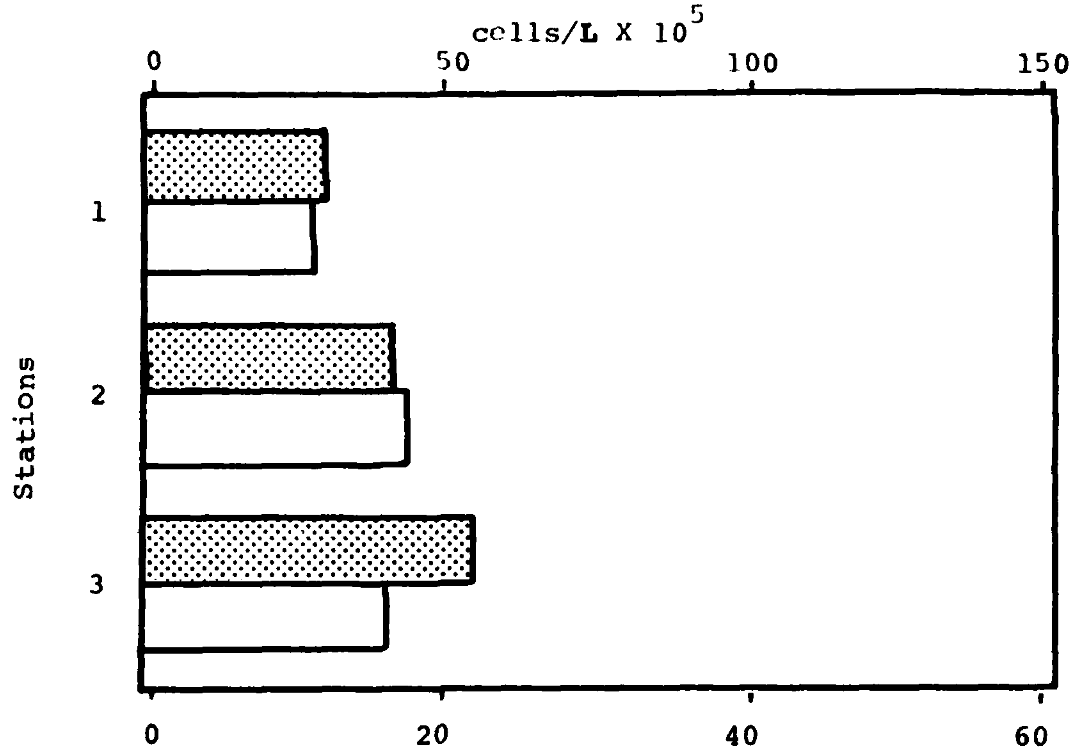


Figure E-3 . Phytoplankton cell counts and chlorophyll a values for collections at stations in the Tennessee Colony area of the Trinity River.

October 2, 1971



October 16, 1971

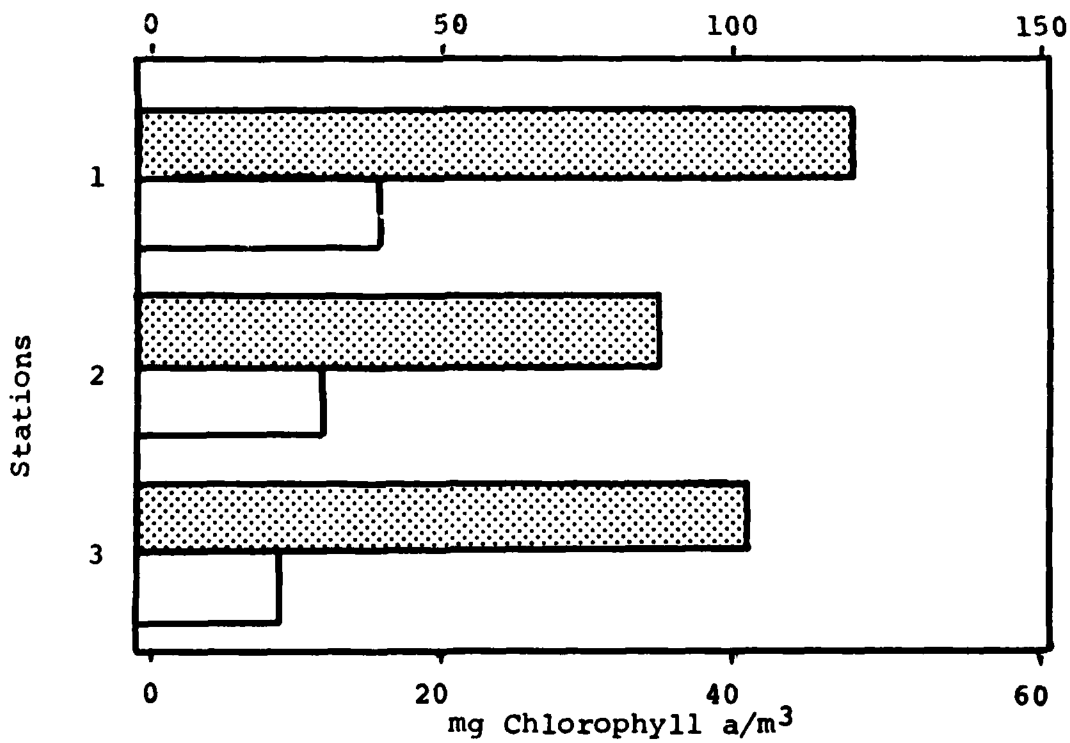


Figure E-3. continued

November 4, 1971

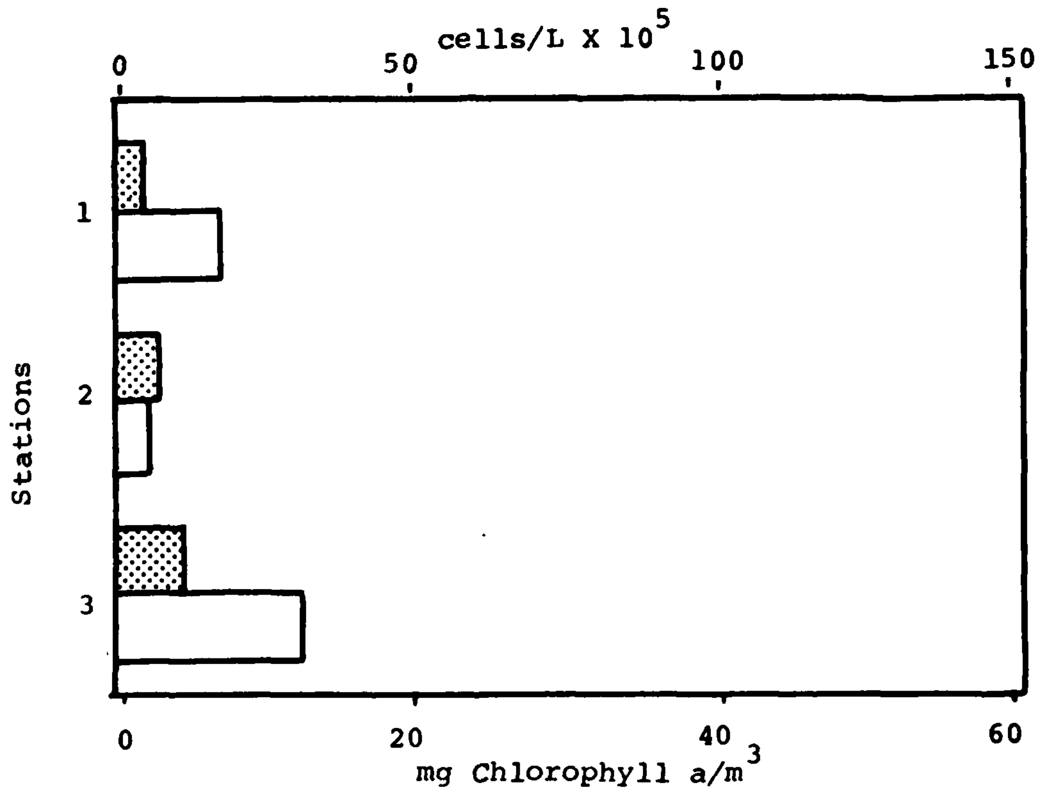


Figure E-3. continued

TABLE E-3

DISCHARGE RATES for the TRINITY RIVER TAKEN at U. S. GEOLOGICAL SURVEY STATION near LONGLAKE, TEXAS

Sept. 4, 1971	100 CFS
Sept. 18, 1971	344 CFS
Oct. 2, 1971	875 CFS
Oct. 16, 1971	598 CFS
Nov. 4, 1971	3,897 CFS
Nov. 27, 1971	5,115 CFS

TABLE E-4

DIVERSITY INDEX VALUES for PERIPHYTON COMMUNITIES COLLECTED at the TENNESSEE COLONY AREA of the TRINITY RIVER

Station	1	2	3	3A	3B
Sept. 4, 1971	-	-	2.5	0.9	-
Sept. 28, 1971	1.9	2.5	2.3	0.8	-
Oct. 14, 1971	2.1	2.3	2.5	2.2	-
Oct. 28, 1971	1.3	2.1	2.1	2.1	1.6
Nov. 12, 1971	-	-	1.9	1.6	1.5

TABLE E-5

LIST OF PHYTOPLANKTON AND RELATIVE ABUNDANCE* BY STATIONS
IN THE TENNESSEE COLONY AREA OF THE TRINTIY RIVER

Stations	1	2	3
CHLOROPHYTA			
Actinastrum sp.	O	O	O
Ankistrodesmus sp.	-	O	O
Chlamydomonas sp.	A	F	F
Chlorella spp.	D	D	D
Closterium sp.	R	R	-
Coelastrum sp.	O	O	O
Crucigena sp.	-	F	F
Golenkinia sp.	-	-	R
Micractinium sp.	F	A	A
Micrasterias sp.	-	0	-
Pandorina sp.	O	-	O
Pediastrum sp.	O	-	O

TABLE E-5. CONTINUED

Scenedesmus acuminatus	-	O	F
Scenedesmus dinticulatus	-	-	O
Scenedesmus quadricauda	A	A	F
Spinoclosterium sp.	R	-	O
Staurastrum sp.	-	-	R
CHRYSOPHYTA			
Bascillariophyceae			
Coscinodiscus Rothii	-	R	-
Cyclotella Kutzingiana	-	-	O
Cyclotella Meneghiniana	O	O	O
Cyclotella sp.	O	-	O
Cymbella ventricosa	-	O	R
Eunotia pectanalis	-	O	-
Frustulia rhomboides	R	-	R
Gomphonema angustatum	-	-	F
Gomphonema olivaceum	-	O	O
Gomphonema parvulum	O	-	-

TABLE E-5. CONTINUED

Melosira herzogii	R	O	O
Navicula accomoda	-	-	R
Navicula biconica	O	-	-
Navicula canalis	-	R	O
Navicula cryptocephala	O	O	O
Navicula gastrum	-	O	-
Navicula insignita	O	-	-
Navicula pygmaea	-	R	-
Navicula sp.	R	-	-
Neidium temperei	-	-	R
Nitzschia acicularis	-	O	O
Nitzschia amphibia	O	R	O
Nitzschia palea	F	F	F
Nitzschia parvula	-	-	O
Nitzschia sp.	-	O	O
Synedra sp.	R	-	R

TABLE E-5. CONTINUED

CYANOPHYTA			
<u>Merismopedia</u> <u>sp</u>.	O	-	R
<u>Oscillatoria</u> <u>sp</u>.	O	O	F
EUGLENOPHYTA			
<u>Euglena</u> <u>oxyuris</u>	-	-	O
<u>Euglena</u> <u>sp</u>.	F	F	F
<u>Phacus</u> <u>sp</u>.	F	O	F

*Abundance is based upon the following scale:

D - Dominant

A - Abundant

F - Frequent

O - Occasional

R - Rare

- - Not observed

TABLE E-6

LIST OF PERIPHYTON DIATOMS AND THEIR RELATIVE ABUNDANCE* BY STATIONS IN THE TENNESSEE COLONY AREA OF THE TRINITY RIVER

Stations	1	2	3	3A	3B
Anomoeneis serians	-	R	-	-	A
Cyclotella Kutzingiana	O	-	O	-	-
Cyclotella Meneghiniana	O	O	F	O	R
Cyclotella stelligera	-	-	R	-	-
Cyclotella striata	-	-	R	-	-
Cymbella ventricosa	R	-	R	R	-
Diploneis smithii	-	-	R	R	-
Frustulia rhomboides	R	R	-	R	-
Gomphonema acuminatum	C	O	O	R	-
Gomphonema angustatum	F	F	F	F	R
Gomphonema olivaceum	-	-	F	O	-
Gomphonema parvulum	D	D	D	D	-
Gyrosigma scalproides	-	O	-	-	-
Melosira herzogii	O	-	-	-	-

TABLE E-6. CONTINUED

Navicula biconica	F	O	A	F	-
Navicula cryptocephala	O	R	O	-	O
Navicula cuspidata	-	-	-	R	-
Navicula elginensis	R	-	O	R	-
Navicula exigua	-	O	O	R	-
Navicula gastrum	-	O	O	O	-
Navicula insignita	O	-	-	-	-
Navicula laterostrata	-	-	-	F	-
Navicula mobiliensis	-	-	R	O	-
Navicula muralis	-	-	O	O	-
Navicula rhyncocephala	-	-	o	-	-
Nitzschia amphibia	-	-	F	O	-
Nitzschia filiformis	-	R	R	-	-
Nitzschia lacunarum	-	O	F	O	-
Nitzschia Lorenziana	-	-	R	-	-
Nitzschia palea	A	A	F	A	F
Nitzschia parvula	O	O	O	O	R

TABLE E-6. CONTINUED

Nitzschia sublinearis	O	O	-	-	-
Nitzschia thermalis	-	-	R	R	-
Pinnularia biceps	R	-	R	-	-
Stauroneis anceps	-	O	A	A	-
Synedra acus	-	-	O	O	D
Synedra ulna	R	-	F	F	-

*Abundance is based upon the following scale:

D - Dominant

A - Abundant

F - Frequent

O - Occasional

R - Rare

- - Not observed

Chlamydomonas, and *Scenedesmus* are very common in sewage oxidation ponds.

Hartmann (1965), in a study of the phytoplankton of a eutrophic region of the upper Ohio River, found the genera *Chlamydomonas*, *Ankistrodesmus*, *Scenedesmus*, *Pediastrum*, *Micractinium*, *Crucigenia*, and *Dictyosphaerium* were dominant from June to December.

Evidence of recent sewage discharge is reflected also in the total coliform bacteria analysis. The MPN of total coliform bacteria ranged from 110,000 cells per 100 ml. at Station I and Station III to 2,100 cells per 100ml. at Station III, with a mean for all stations of 43,072 cells per 100 ml. (Table E2). Interestingly, all three stations revealed high coliform counts on November 4, 1971, when the flow rate was 3,897 CFS, a flood condition.

Standing crop and productivity of the periphyton was comparatively high (Fig. E4). The mean standing crop biomass of periphyton ranged from 165 grams of dry weight per square meter at Station III on October 2, 1971 to 1.5 g. dry wt./m^2 at Station III on November 12, 1971 with a mean of 32.9 g. dry wt./m^2. Expressed as ash free dry weight, the mean standing crop was 6.9 grams/m^2. Odum (1957) obtained a periphyton standing crop of 177 g. dry wt./m^2 in Silver Springs, Florida. Cushing (1966) obtained a mean periphyton standing crop of 4.2 g. dry wt./m^2 in the Columbia River, and McConnell and Sigler (1959) obtained a value of 25 g. dry wt./m^2 in

Table E-2

MPN VALUES for TOTAL COLIFORM ANALYSIS from WATER SAMPLES COLLECTED at the TENNESSEE COLONY AREA of the TRINITY RIVER

MPN values in organisms per 100 ml.

Station	1	2	3
Sep. 18, 1971	110,000	2,800	2,100
Oct. 2, 1971	2,300	9,300	110,000
Oct. 16, 1971	-	-	4,300
Nov. 4, 1971	24,000	75,000	110,000
Nov. 12, 1971	-	-	24,000

- Indicates no samples taken

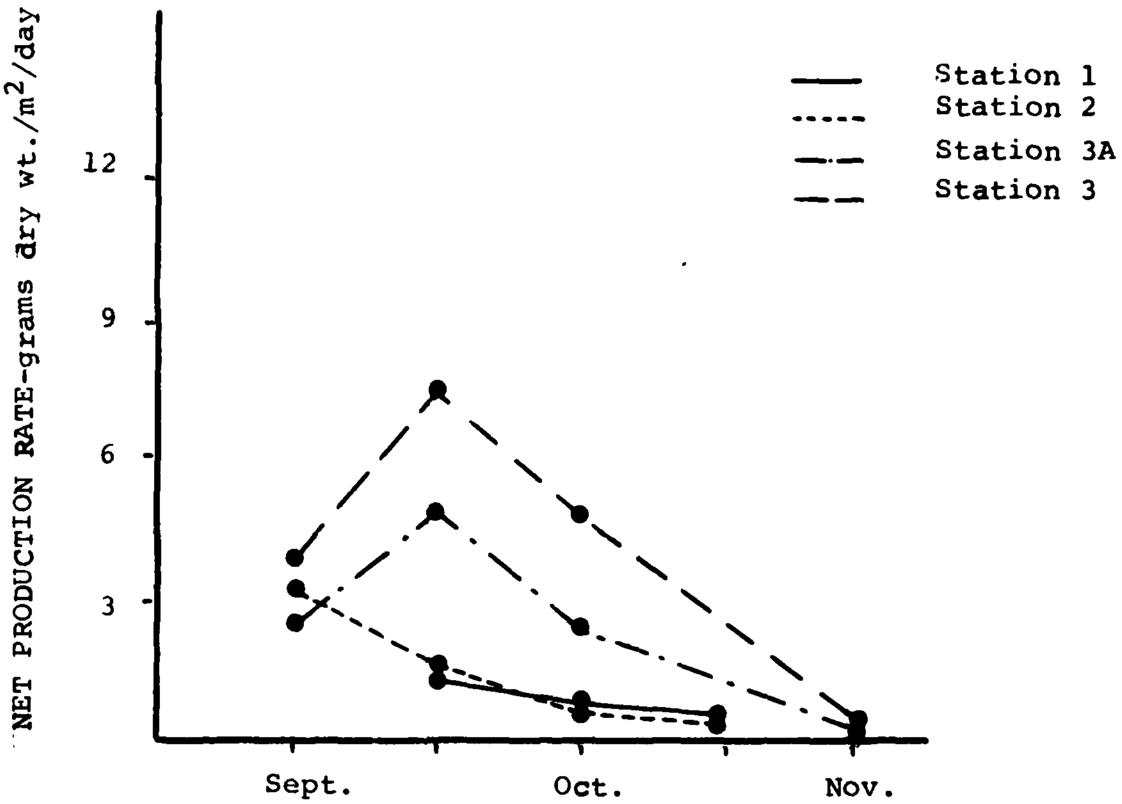


Figure E-4. Net production rate of periphyton in the Tennessee Colony Area of the Trinity River, September to November 1971.

Logan River, Utah. McIntire (1964) obtained a periphyton biomass of 187 g. dry wt./m^2 in artificial streams.

Primary productivity of the periphyton was also relatively high compared with values in the literature. The productivity ranged from 11,817 mg. dry wt./m^2/day at Station III to 112.7 mg. dry wt./m^2/day at Station III with a mean for all staions of 2,355.6 mg. dry wt./m^2/day. The mean production rate expressed as ash free dry weight was 493.1 mg. ash free dry wt./m^2/day.

Odum (1957) reports the highest periphyton production rates of 12,400 mg. dry wt./m^2/day in Silver Springs, Florida. Cushing (1966) obtained a production rate of 290 mg. dry wt./m^2/day in the Columbia River.

The range of production rates obtained in this study clearly approach the highest rate reported by Odum (1957). In Silver Springs, Florida the water was quite clear allowing an abundance of light for algae growth. In the Trinity River the water is quite enriched with nutrients, but the high turbidity probably causes light to be the factor limiting productivity in the periphyton. This study was carried out in autumn when normally primary production rates in rivers are declining because of reduced light conditions, and mean values include several rates determined in flood stages. It is the opinion of this writer that Odum's maximum productivity rate for periphyton would be exceeded if determinations had been taken in summer without flood conditions.

A check list, including the relative abundance of periphytic diatoms may be found in Table E6. Gomphonema parvulum and Nitzschia palea were often the dominant diatoms in the periphyton collections. Weber and Raschke (1970) found in their study, that Gomphonema parvulum and Nitzschia palea indicated high levels of dissolved organics (high organic pollution). Butcher (1947) and Fjerdinstad (1964) both report the two diatoms to be associated with polluted waters. Hornung (1959) reports Gomphonema angustatum, also common in periphyton collections of this study, to be present in highly polluted waters. Kolkwitz (1950) and Liebmann (1951) have associated Nitzschia palea with the alpha-mesosaprobic zone of a polluted stream. Weber and Raschke (1970) also associated the occurance of the diatom Cocconeis placentula with oligosaprobic conditions and low or moderate dissolved organics. It is perhaps significant to point out that Cocconeis placentula was never found in any periphyton collections in this study.

Cladophora glomerata was frequently observed on submerged wood surfaces and stones during September and October. Blum (1960) reports that this species is tolerant of very high amounts of sewage in water with a weak salinity.

Although not part of the periphyton, it might be appropriate to mention at this point that during September and October, excessive growths of "Duckweed" (Lemna sp.) were observed in protected branches of the river and around "logjams." This plant is a small floating vascular plant which can develop an enormous standing crop in lakes and ponds

Channelization of the river and the construction of an impoundment may have numerous effects on eutrophic conditions. Channelization should require removal of the extensive vegetation which has developed along the river banks, now so abundant in some regions of the river, that the water receives direct sunlight for only a short period of time during the day. The increased exposure of the water to direct sunlight will probably have several effects. Light is probably the factor limiting primary productivity in the phytoplankton and periphyton, and may cause great increases in the standing crop of both communities of plants. Increased exposure of the water to direct sunlight may also result in an increase in water temperature, which is commonly associated with increases of blue-green algae populations. The blue-green algae include many of the nuisance algae of water works. The increased temperature would also reduce the solubility of dissolved oxygen in a river which already has low oxygen concentrations. Wharton (1970) reports that the removal of stream-side vegetation takes away the root-bound banks which often impede erosion and partially immobilize silt. Wharton further mentions that channelization increases the stream gradient and decreases the retention time of the water mass, resulting in a more rapid transport of silt and an increase in turbidity.

As the river waters enter the reservoir, the velocity will become reduced, thus, reducing the competency and capacity of the water mass. The result will be the release of a portion of the suspended load in the water and an increase in the transparency. At the point where the river joins the reservoir, the water will probably be characterized by high concentrations of nutrients and increased transparency. This region of the lake should support dense masses of aquatic weeds and frequent algae "bloom" development. The effects of this development have been encountered in the past: disagreeable taste and odor of drinking water, large masses of decaying algae on leeward shores, clogging of intake filters, and a depletion of oxygen caused by decomposing vegetation.

The probable downstream effects on eutrophic conditions resulting from the proposed Tennessee Colony impoundment are varied. The impoundment will probably result in the removal of a significant quantity of silt and nutrients from the water so that the water released from the reservoir may be of improved quality. However, there are certain conditions which may develop that could result in other effects. The lake should be sufficiently deep to allow periodic thermal stratification, particularly during the summer months. Prolonged stratification would result in anaerobic or near anaerobic conditions in the hypolimnion, accompanied by an increase in nutrients. The release of water from this zone of the water mass would have deleterious effects on biological conditions downstream. Increased nutrients in this water would increase eutrophic condtions downstream, and the reduced dissolved oxygen could be too low to handle downstream BOD. By continual release of water from the hypolimnion, there would probably be an impact on the heat budget of the lake, resulting in increased water temperature. Higher water temperatures would increase the evaporative loss, perhaps resulting in an increase in salinity.

Although stratification may occur periodically, the morphometry of the lake and persistent wind action will probably result in frequent mixing of the water mass and will prevent extended periods of stratification, thus ameliorating problems associated with stratification.

As the recreational potential of the impoundment is developed, construction of homes and camping sites should increase around the lake, accompanied by the installation of numerous septic tanks and cesspools. This may become a pollution problem, contributing to the eutrophic conditions of the impoundment.

The upper portion of the proposed Tennessee Colony impoundment will probably be the most critical region from a eutrophication standpoint. Frequent monitoring of this region should be done by assessing phytoplankton standing crop and/or frequent pH and dissolved O_2 measurements which could be used as an early indicator of "bloom" development. The development of nuisance algae and vascular plants may require periodic application of herbicides as a countermeasure. This is a rather undesirable alternative as it would contribute to pesticide pollution of the aquatic environment. Continual improvement of upstream treatment facilities for domestic and industrial sewage would, of course, offer the most acceptable way to alleviate the problem.

2. Diversity Index:

Diverstiy index values derived from periphyton diatom communities are given in Table E4 and range between 2.5 at Station II and III, to 0.8 at Station III-A, with a mean diversity index of 1.9 for all stations. The interpretation of the diversity index values are based on the work of Wilhm and Dorris (1968) who suggested that diversity values of less than 1.0 indicate heavy pollution, values of 1.0 to 3.0 indicate moderate pollution, and values greater than 3.0 indicate clean water. Staub (1970) proposed that diversity values from 0.0 to 1.0 indicated heavy pollution, 1.0 to 2.0 moderate pollution, 2.0 to 3.0 light pollution, and 3.0 to 4.5 as slight pollution. By these standards, the mean diversity index of 1.9 could be interpreted as moderate pollution for the Tennessee Colony area of the Trinity River, with some local areas periodically indicating heavy pollution. In September, 1971. diversity values of 0.9 and 0.8 were recorded at Station III-A below the NIPAC plant outfall, compared with diveristy values of 2.5 and 2.3 at Station III above the outfall. Although this suggests a periodic impact on biological conditions in the river immediately below the outfall, there is no evidence to suggest any prolonged effects downstream with a diversity value of 2.5 recorded at Station II during the period when the diversity index was 0.8 at Station III-A. The ammonia, pH, or perhaps the sulfate content of the effluent may be introducing some toxicity to the river near the outfall. Forrest and Cotton (1970) report periodic discharges of 176 ppm of P_2O_5 in the NIPAC effluent; however, only orthophospates were analyzed in this study. On November 27, 1971, a second discharge was observed flowing in a temporary ditch leading from a holding pond near the plant to the river. The ammonia content was determined to be 5,400 ppm ammonia-nitrogen. This outfall was not seen at other collecting times. The river was in flood stage during the period and no diversity values near the point of discharge were obtained to determine the impact of this discharge.

Although the data suggest that the NIPAC effluent does not have a prolonged effect downstream the location of the outfall with respect to the proposed reservoir is unfortunate. As previously described, the upper portion of the reservoir should be most critical from a eutrophication point of view. The NIPAC effluent will probably be contributing some toxicity and nutrients to an aquatic environment already disturbed and under stress from excessive nutrients and other pollutants from upstream. The impact of the

NIPAC effluent on the proposed reservoir should be kept under close surveilance.

3. Pesticide Element:

The amount of phenoxy herbicides used for agricultural purposes in 1970 within Navarro, Freestone, Henderson, and Anderson counties may be found in Table E9 . The estimated amounts of insecticides used for agricultural purposes for a three year period in the four county area and the estimates of acreages treated are given in Tables E8 and E7 respectively. Navarro county leads in both the amounts of herbicides and insecticides used in 1970. It is perhaps significant to note the high estimates of DDT used in Navarro county: 60,000 lbs. in 1969 and 22,650 lbs. in 1970. Also of interest are the high estimates of carbaryl usage in each of the counties. The high productivity of cotton in Navarro county accounts for the high estimates of DDT while the high estimates of carbaryl were due to its probable use on a variety of crops such as grains, field corn, and forage crops as well as cotton. In the four county area, run-off from the fields where these pesticides are used, probably introduces these pollutants into the Trinity River.

The pesticide concentrations in the Trinity River appear to be comparatively low (Table E10). However, the data suggests that the concentrations of pesticides are higher in the upper portion of the Trinity River than in the lower

TABLE E-7
ESTIMATES OF INSECTICIDE USE IN AGRICULTURE - 1968 to 1970

Anderson, Freestone, Henderson, and Navarro Counties

County	Year	Cumulative Acres Treated							
		Cotton	Sorghum	Field Corn	Wheat	Other Grain	Forage Crops	Fruits & Nuts	Veg.
Anderson	1968	1500	-	-	-	-	-	36	5800
	1969	1800	200	-	-	-	8500	-	1600
	1970	1227	4500	3000	-	20700	-	1200	12800
Freestone	1968	-	280	-	-	400	350	2000	-
	1969	600	-	-	-	-	-	3250	-
	1970	1800	-	200	-	200	4000	2800	-
Henderson	1968	100	1000	300	0	0	0	100	7500
	1969	300	-	-	500	-	75000	100	5000
	1970	300	-	-	-	-	7500	100	7000
Navarro	1968	40000	17000	-	-	400	900	800	500
	1969	40000	5000	-	1000	5000	2500	1000	500
	1970	15100	10000	-	3000	10000	35000	-	1000

TABLE E-8

ESTIMATES OF INSECTICIDE USAGE
ANDERSON, FREESTONE, HENDERSON, AND NAVARRO COUNTIES

YEARS	1968	1969	1970
ANDERSON COUNTY			
Insecticides (total lbs. used)			
Carbaryl	4,730	6,581	23,111
DDT	2,250	2,700	1,840
Diazinon	580	160	1,280
Guthion	37	-	1,260
Malathion	1,110	730	4,313
Methyl parathion	328	393	643
Parathion	464	780	3,990
Toxaphene	1,875	2,533	1,533
FREESTONE COUNTY			
Insecticides (total lbs. used)			
Carbaryl	8,430	13,256	14,231
DDT	-	900	2,700
Diazinon	-	-	-
Guthion	2,100	3,412	2,940
Malathion	1,305	2,048	1,974
Methyl parathion	-	131	418
Parathion	1,708	2,633	2,583
Toxaphene	11	750	2,383
HENDERSON COUNTY			
Insecticides (total lbs. used)			
Carbaryl	6,271	49,352	10,202
DDT	150	450	450
Diazinon	750	500	700
Guthion	105	105	105
Malathion	1,494	4,776	1,751
Methyl parathion	59	65	65
Parathion	756	6,119	1,168
Toxaphene	125	2,875	625

TABLE E-8. CONTINUED

NAVARRO COUNTY

Insecticides (total lbs. used)

Carbaryl	10,525	13,975	28,009
DDT	60,000	60,000	22,650
Diazinon	50	50	100
Guthion	840	1,050	-
Malathion	1,088	706	2,838
Methyl parathion	8,750	8,750	3,303
Parathion	2,696	2,048	4,800
Toxaphene	50,030	50,083	20,041

TABLE E-9

HERBICIDE USAGE IN ANDERSON, FREESTONE, HENDERSON, AND NAVARRO COUNTIES, 1970

County	Gallons Phenoxy-herbicide
Anderson Co.	1622
Freestone Co.	782
Henderson Co.	5100
Navarro Co.	6529

TABLE E-10

PESTICIDES IN TEXAS SURFACE WATERS, 1970
TRINITY RIVER NEAR ROSSER, TEXAS

(Results in micrograms per liter)

Date of collection	Dec. 2, 1969	Apr. 7, 1970	June 2, 1970	July 9, 1970	Aug. 5, 1970
Time (24 hour)	1730	1015	1505	1645	1115
Discharge (cfs)	510	4850	11300	564	577
INSECTICIDES					
Chlorinated hydrocarbons:					
Aldrin	0.00	0.00	0.00	0.00	0.00
DDD	.04	.01	.01	.02	.02
DDE	.00	.00	.00	.00	.00
DDT	.14	.02	.01	.01	.00
Endrin	.00	.00	.00	.00	.00
Dieldrin	.09	.02	.02	.25	.00
Heptachlor	.00	.00	.00	.00	.00
Heptachlor epoxide	.00	.00	.00	.00	.00
Lindane	.00	.00	.03	.05	.00
Chlordane	.41	.20	.06	.37	.13
Toxaphene	0	0	0	0	0
Alpha-BHC	.00	.00	.01	.00	.00
Phosphorothioates:					
Parathion	.00	.00	.00	.00	.00
Methyl parathion	.00	.00	.00	.00	.00
Malathion	--	--	--	--	--
Diazinon	.00	.00	.00	.00	.00
HERBICIDES					
Chlorinated hydrocarbons:					
2,4-D	.45	.12	.14	1.2	1.6

TABLE E-10. CONTINUED

Silvex	.00	.00	.01	.00	.00
2,4,5-T	.06	.02	.10	.06	.02

TRINITY RIVER AT ROMAYOR, TEXAS

(Results in micrograms per liter)

Date of collection	Oct. 7, 1969	Feb. 20, 1970	Apr. 30. 1970	June 25, 1970	Aug. 13, 1970
Time (24 hour)	1150	1005	1300	1240	1545
Discharge (cfs)	1560	4430	3460	2760	1300
INSECTICIDES					
Chlorinated hydrocarbons:					
Aldrin	0.00	0.00	0.00	0.00	0.00
DDD	.00	.12	.00	.00	.00
DDE	.00	.05	.00	.00	.00
DDT	.00	.22	.00	.00	.00
Endrin	.00	.00	.00	.00	.00
Dieldrin	.00	.00	.01	.00	.00
Heptachlor	.00	.00	.00	.00	.00
Heptachlor epoxide	.00	.00	.00	.00	.00
Lindane	.00	.01	.00	.00	.00
Chlordane	.0	.0	.0	.0	.0
Toxaphene	0	0	0	0	0
Phosphorothioates:					
Parathion	--	.00	.00	.00	.00
Methyl parathion	--	.00	.00	.00	.00
Malathion	--	--	--	--	.00
Diazinon	--	.00	.00	.00	.00

TABLE E-10. CONTINUED

HERBICIDES					
Chlorinated hydrocarbons:					
2,4-D	.05	.05	.07	.09	.05
Silvex	.00	.00	.00	.00	.00
2,4,5-T	.02	.03	.02	.03	.02

end of the river. This observation seems reasonable considering the extensive agricultural activity in such counties as Navarro, near the Tennessee Colony site. The concentrations of pesticides in the river water would be expected to decrease progressively as the water mass moves downstream from the point of application. Bailey and Hannum (1965) mention that pesticide concentrations in river waters decreased at a rate of about 0.0016 micrograms per liter per mile downstream from the point of application. The pesticide condentrations in Table E10 reflects results of water sample analysis, so that concentrations in the sediments may be considerably higher. DDT, for example, is relatively insoluble in water. Bailey and Hannum have reported pesticide concentration in river sediments exceeded those in water 20 to 100 times, with the concentrations being proportionately higher in fine sediments. Wharton (1970) reports that DDT and other pesticides, owing to their affinity for silt, would be trapped by sediments as the silt is deposited in a reservoir.

The insecticides Chlordane, DDT, and Dieldrin, and the herbicide 2, 4-D were present in the highest concentrations at the upstream station according to USGS data. Toxaphene, a cholorinated camphene, was not detected at either station, which is rather surprising considering that Toxaphene-DDT combination is probably used as an insecticide on cotton crops. Klein (1962) reports that Toxaphene is one of the most toxic insecticides.

Many of the phosphorus compounds are degradable and short-lived in contrast with the chlorinated hydrocarbons which are quite persistent. It is the persistent nature of compounds such as DDT which causes concern from an ecological and public health point of view. The compounds tend to increase concentrations progressively at higher levels in the food chain. Mack (1964), for example, found that fish in his study contained concentrations of DDT that were significantly higher than the surrounding muds.

While much information has been published on the toxicology of aquatic organisms, including pesticides, the establishment of an acceptable concentration of a single toxicant for one species in one type of water still needs experimental work. Niering (1971) reviewed the adverse effects of pesticides which pose a threat to the biota. These are: (1) killing non-target organisms, (2) accumulation of pesticides in the food chain, (3) lowering of reproductive potential, especially among birds, (4) resistance of insect pests to insecticides, (5) synergistic effects (interaction of two compounds which may result in a third much more toxic than either one alone), (6) chemical migration to areas not treated with insecticide, (7) accumulation in the ecosystem of some pesticides since some are not broken down by biological agents and (8) a delayed response of certain insecticides after application.

The data suggest that the insecticide and herbicide levels in the water are suitably low, but future surveys should include sediment analysis as well as water analysis for pesticides. The levels of pesticides should be monitored in the proposed reservoir to detect future increases.

CONCLUSIONS

1. Nutrient levels such as nitrate-nitrogen and orthophosphates indicate excessive eutrophic conditions.
2. Excessive populations of phytoplankton and periphyton were found in the Trinity River, indicative of a high degree of eutrophication.
3. Rates of primary production in the Tennessee Colony area of the Trinity River are comparatively high.
4. The species of algae in the phytoplankton and periphyton are those commonly associated with organic pollution.
5. The high MPN values for total coliform bacteria suggest that sewage effluent is the primary source of organic pollution.
6. Diversity Index values indicate a moderately polluted environment with heavy pollution periodically indicated near the NIPAC, Inc. outfall.
7. The removal of streamside vegetation in channelization will probably increase the standing crop of algae; increase water temperature; reduce the oxygen saturation values; increase bank erosion and perhaps increase turbidity.
8. The upper portion of the proposed reservoir should be the most critical region from a eutrophication standpoint, because of increased water transparency and high nutrient levels.

9. Eutrophic conditions should be reduced below the proposed reservoir by nutrient and silt removal in the impoundment.

10. Prolonged thermal stratification and water release from the hypolimnion of the proposed reservoir could cause nutrient enrichment and low dissolved oxygen values downstream; however, this problem will probably be minimal because the lake morphometry and wind action may not allow the lake to stratify for extended periods.

11. Estimates of insecticide and herbicide usage are high for some counties in the Tennessee Colony area of the Trinity River, such as Navarro County; however, the pesticide levels in the river water appear to be suitably low.

RECOMMENDATIONS

1. The proposed reservoir should be monitored closely for the development of excessive standing crops of algae and aquatic vascular plants, perhaps using chemical treatment as a countermeasure.
2. Facilities for treatment of domestic and industrial sewage upstream should be continuously improved to reduce eutrophic conditions in the reservoir area.
3. It is recommended that a "follow-up" study be done subsequent to the construction of the proposed reservoir to compare the eutrophic conditions in the lake and river with pre-impoundment data.
4. The installation of septic tanks and cesspools adjacent to the proposed reservoir should be controlled so that they do not become a pollution problem.
5. The impact of the NIPAC, Inc. waste discharges on the proposed reservoir should be kept under close surveillance.
6. Levels of pesticides should be monitored in the proposed reservoir.
7. Future surveys of pesticides should include sediment analysis as well as water analysis.

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